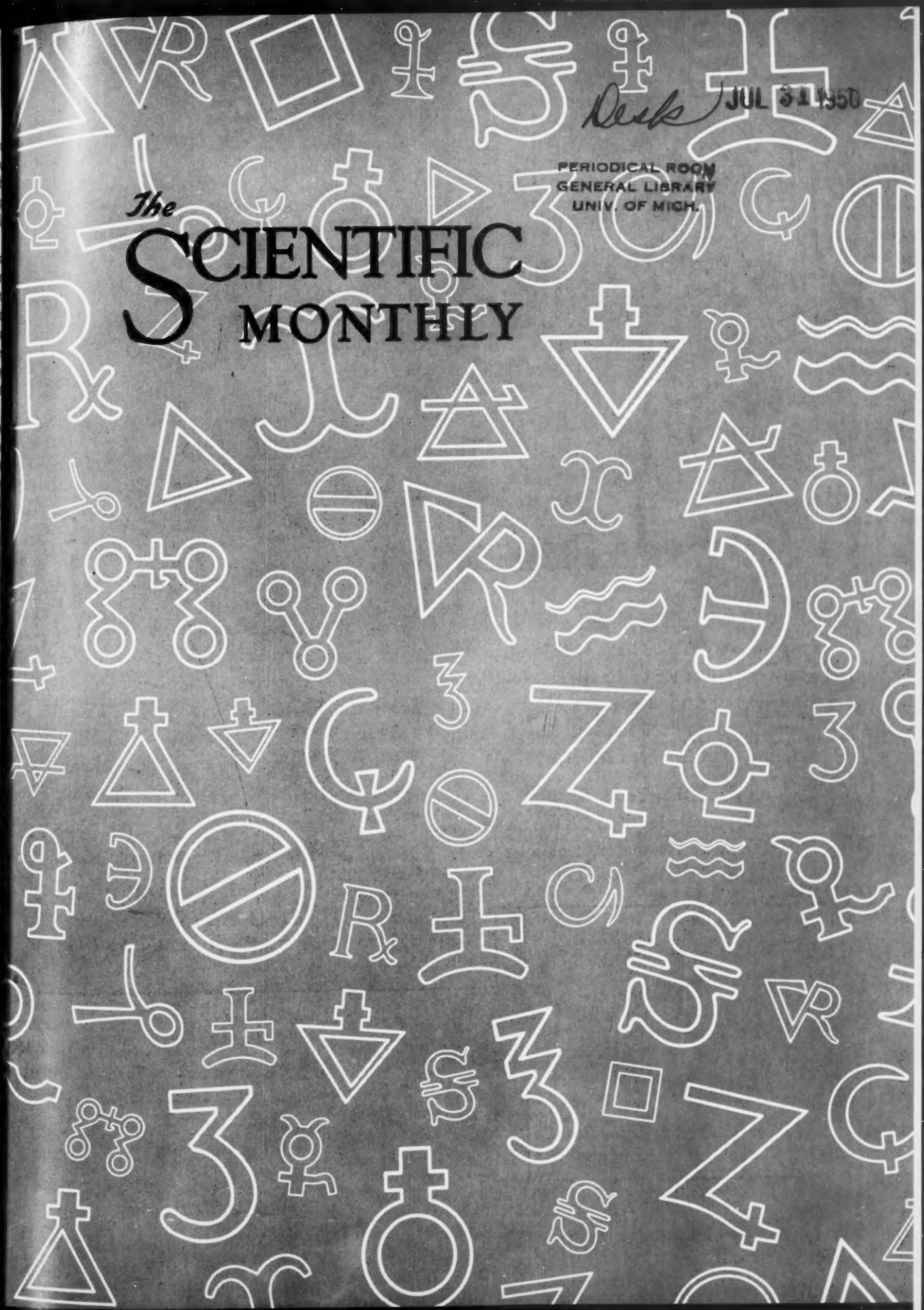

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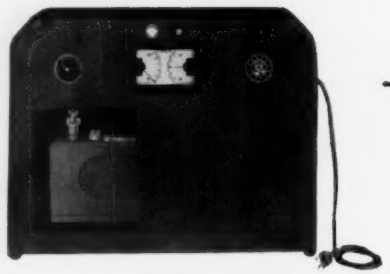

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Annual Meeting, AAAS, Cleveland, Ohio, December 26–30, 1950

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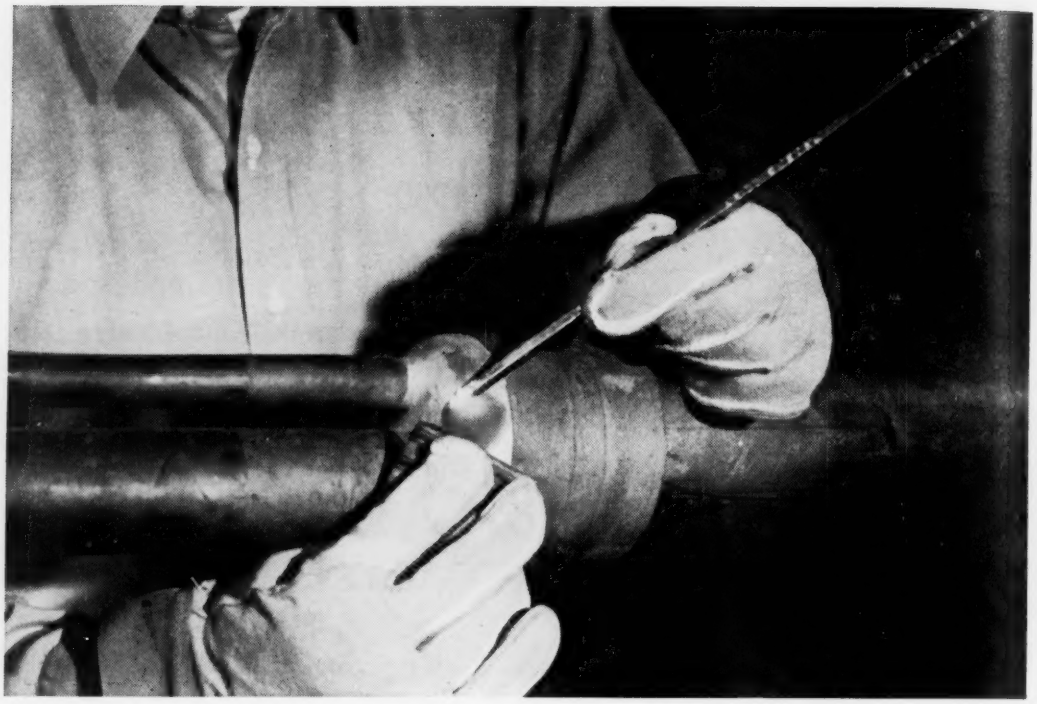

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THE SCIENTIFIC MONTHLY

AUGUST 1950

Ecological Problems of Southeastern Brazil

PIERRE DANSEREAU

Founder (1943) and director (1943–50) of the Service de Biogéographie, of the Université de Montréal, the author (D.Sc., Geneva, 1939) will become assistant professor of botany at the University of Michigan next October when he returns from his work with the Clyde River (Baffin Land) Expedition of the Arctic Institute of North America. His principal interest is in ecology.

BRAZILIAN geographers have divided their country into five main regions: the North (Acre territory, states of Amazonas and Pará); the Northeast (states of Maranhão, Piauí, Ceará, Rio Grande do Norte, Paraíba, Pernambuco, and Alagõas); the East (states of Sergipe, Bahia, Minas Gerais, Espirito Santo, Rio de Janeiro, and the Federal District); the South (states of São Paulo, Paraná, Santa Catarina, and Rio Grande do Sul); the Center-West (states of Goiáz and Mato Grosso). The Northeast and the East are further subdivided into a northern and southern part.[12]

Geographically, the *Leste Meridional,* therefore, comprises the states of Minas Gerais, Espirito Santo, Rio de Janeiro, and the Federal District. This delimitation is based on many things besides relief, climate, and vegetation. A cursory glance at maps showing these features immediately reveals the variety of situations to be encountered. (See map published in 1945 by the Conselho Nacional de Geografia.) It is not a very homogeneous area.

Physiographically, the dominating feature is the presence of the coastal ranges, a high, Pre-Cambrian, well-eroded rampart that borders the eastern edge of the great central Brazilian plateau (or Planalto) and is essentially responsible for rainfall patterns and for the resulting vegetation.

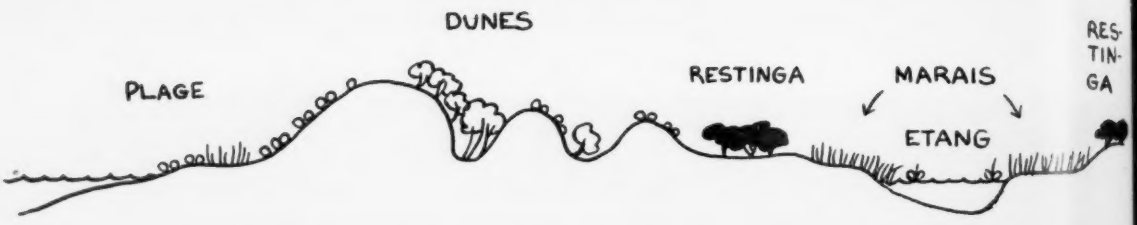
Climatically, in the terms of Köppen's[14] classification, it lies mostly within the coastal Af-Am belt, with abundant and rather evenly distributed precipitation; but it encroaches also upon the Aw and Cw zones with their dry seasons.

Floristically, Schouw[25] had called this general area "the land of melastomes and palms," and it is true that these two families are very highly developed there. But the tropical element is not the only one involved, as many temperate groups appear with altitude and toward the south.

Vegetationally, tropical rain forest dominates. Rübel[23] includes it in his *laurilignosa.* With altitude, montane forest is substituted, and eventually elfin forest; whereas toward the interior savanna (or *cerrado*) appears.

From a *land-use* point of view, Oliveira[16] calls it the zone of "tropical ploughed land" in contrast to the extensive pastures of the hinterland.

I shall not attempt to consider all of southeastern



Profile showing physiognomy and zonation of vegetation along the seacoast of Rio de Janeiro.

Brazil, but will draw a transect closely parallel to the Tropic of Capricorn. This should permit a view of several types of vegetation, in response to physiography and climate. It also allows some considerations of the dynamics of the living environment and its relation to human interference. Thus, many interesting ecological as well as floristic problems are posed to the naturalist. It will be worth while to take the occasion of this brief general description of the landscape to point out some of the most significant issues.

As far as plant and animal communities are concerned, four principal areas can be recognized: the plain, or lowlands, the escarpment, the inner valleys, and the mountains. Beyond this extends the central plateau, with its predominantly savanna vegetation, a response to a drier climate. There lie other conditions and other problems that will not be reviewed here.

The Coastal Plain

The physiography of the lowlands is determined by the breakdown of the Pre-Cambrian mountain ranges and their more or less isolated outcrops in the plain and out into the sea. Overlying this basic structure are some Tertiary outcrops and considerable Quaternary and Recent sediments. Because of the various shifts of these elements, there is a well-differentiated topography which offers a number of substrata to plant and animal life and therefore to man.

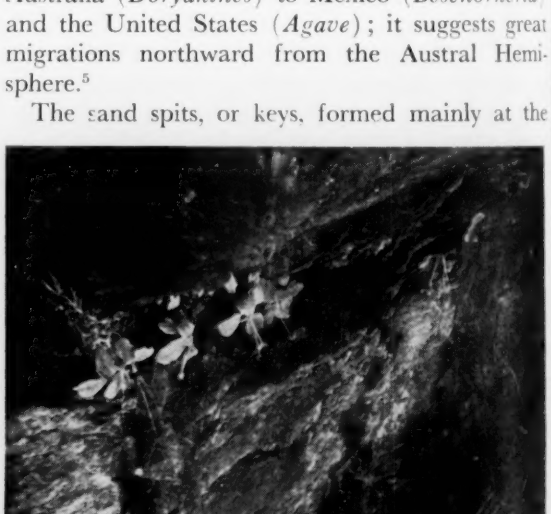
The Pre-Cambrian rocks—of which the famous Sugar Loaf is a typical example—present variously polished or corrugated surfaces. The steeper cliffs harbor a lichen and bromeliad flora, whereas lesser inclines permit other, heavier bromeliads, orchids, cacti, ferns, and many flowering plants to form tufts or swards of varying luxuriance. Especially remarkable are the large blossoms of the *Brassavola* orchids, the white spikes of *Vellozia candida,* and the strongly phototropic stems of *Cephalocereus fluminensis.* Sometimes *Hohenbergia paniculata,* a robust bromeliad, forms dense colonies. Fires may sweep across them, destroying many plants, but usually not attacking the rhizomes.

Some particularly interesting species and communities occur on coastal cliffs; for example, the ancestor of the showy greenhouse gloxinia (*Sinningia speciosa*) is to be found in moist, shady crevices, a few rather inconspicuous purple-flowered plants in each niche.

Even more remarkable for the biologist is a peculiar community which has formed on well-exposed gneiss: on the vertical wall, water trickles regularly through a mass of blue-green algae, on the surface of which a dense cover of *Lemna montevidensis* has formed. The duckweed is therefore parallel to the rock surface, not moving perceptibly downward in spite of the slowly streaming water, and apparently well anchored in the gelatinous algae.

On the gravelly flat ledges are the big rosettes of *Fourcraea gigantea*: its leaves are of a bright green, almost without prickles, somewhat glossy, and of a thinner texture than those of most of its closest relatives, the *Agaves.* This whole tribe (*Agaveae*) has an interesting distribution, from its outpost in Australia (*Doryanthes*) to Mexico (*Beschorneria*) and the United States (*Agave*); it suggests great migrations northward from the Austral Hemisphere.[5]

The sand spits, or keys, formed mainly at the



Sinningia speciosa (the gloxinia of florists) as it grows in the wild, on the sea cliffs near Rio de Janeiro.

Nidularium, a bromeliad, among a rather dense growth of the dwarf palm, *Diplothemium maritimum.*

mouths of rivers, have become covered, on the seaward side, by typical dune vegetation. Some of the most conspicuous species, such as *Ipomaea pes-caprae* and *Sporobolus virginicus,* have a very wide range on strands in tropical and subtropical America. Others, such as *Scaevola plumieri, Acicarpha spatulata,* are much more restricted. The strands themselves are colonized by a host of very remarkable drought-resisting species, exhibiting a variety of adaptations and occurring in very definite successive belts.[9,20] A conspicuous association is formed by *Diplothemium maritimum,* a palm two to three feet high, with a deeply buried stem that grows downward (like the rhizomes of our *Trillium*) and produces leaves from the underside; it blooms freely almost all year. Ground bromeliads are scattered here, isolated or in colonies; among them is a beautiful *Nidularium,* its compact inflorescence submerged in the "tank." Also, some ferns (such as *Polypodium lepidopteris*) are especially adapted to the habitat, for they can curl up during the dry periods and expand anew when moisture again becomes available.[1] This is the "resurrection-plant" pattern, of which the rose of Jericho (*Anastatica hierochuntica*) is the best-known type. Another xerophyte, a shrub with revolute leaves, *Marcetia taxifolia* (Melastomatacea), occurs farther inland, in more open formations. Its heatherlike habit and bright-purple flowers make it stand out against the white sand, the gray *Cladonia* lichens, and the red-leaved *Paspalum maritimum,* an annual grass. With it also grows *Paepalanthus ramosus,* a big, rather fleshy Eriocaulacea producing enormous umbels of white flower heads and then drying down to a rosette. The delicately colored pink amaryllis, *Hippeastrum psittacinum,* flowers during the summer rains, from a bulb lying aboveground.

Remarkable animals include a burrowing land crab (*Ocypode albicans*), as white as the sand that occupies the upper part of the intertidal zone. This animal has a very broad geographical range, north to New Jersey. Not so the endemic white lizard (*Liolemus lutzae*) that lives under logs deposited by equinoctial tides. A beautiful pink-and-black snake is also found in the same niche. A rare, monotypic amphibian (*Aparasphenodon brunoi*) dwells within the moist tube of the bromeliads. It remains erect all day within its narrow chamber, which it completely obturates with its head, the shape and color of the dead leaves that always accumulate in these plants.[15]

The *restingas,* as these keys are called, are eventually colonized by shrubs of increasing size: the spreading, blue-leaved *Cassia uniflora,* the slender, silvery *Croton migrans,* the coarse, dull green *Byrsonima subsericea,* the mat-forming, red-berried *Chrysobalanus icaco.* Also, several cacti occur, from the tiny *Melocactus violacea* to the large *Cereus variabilis, Pilocereus arrabidea,* and the treelike *Opuntia brasiliensis.*

It is among such open scrub that many exquisitely flavored fruits and nuts mature. The *caju* ("cashew-nut") tree speads its umbrella-shaped branches and its large, scattered leaves. The *pitanga* (*Eugenia uniflora*) produces quantities of acidulous reddish-purple fruit. The guava (*Psidium guajava*) is scattered throughout. Here, in its native habitat, it does not form the dense thickets so characteristic of it in the Pacific areas it has invaded (Fiji and Hawaii).

Open, desertlike formations alternate with dense, wind-shorn thickets where various members of the Rhamnaceae, Malpighiaceae, and Solanaceae dominate. Under shade, and with an increased water reserve, tree species appear toward the inner sections—for instance, various species of the Malvaceae, Sterculiaceae, and Apocynaceae, which form a transition to mesophytic forest.

A grassy depression on the *restinga* between two parallel strips of strand forest.

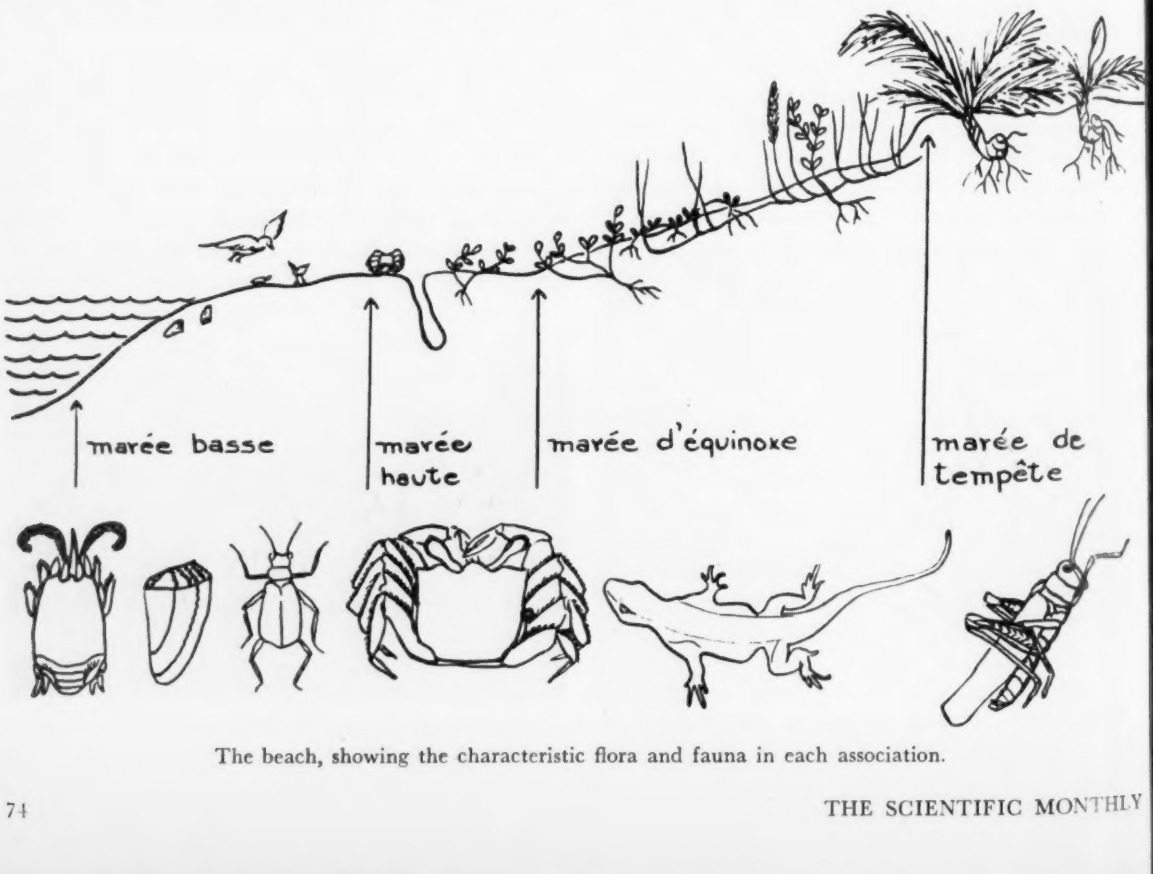
In spite of the very sparse growth of grasses, these strands have been given over to pasture over long periods of time and are thereby considerably modified. Typical are the regularly alternating strips of sward in the moister troughs and scrub forest on the drier ridges that form an often-recurring pattern on the restingas.

The estuaries of the rivers and much of the shoreline are occupied by mangrove. There usually is a triple zonation: *Rhizophora mangle* on the outer fringe of deeper water and finer silt; *Avicennia tomentosa* in shallower water and on coarser sediments; *Laguncularia racemosa* on the upper, usually sandy or gravelly section. Thousands of crabs dwell in the mangrove, where they have bored innumerable holes. They belong to more than a dozen species, each of which is more or less confined to one of the three belts.[9, 17, 18]

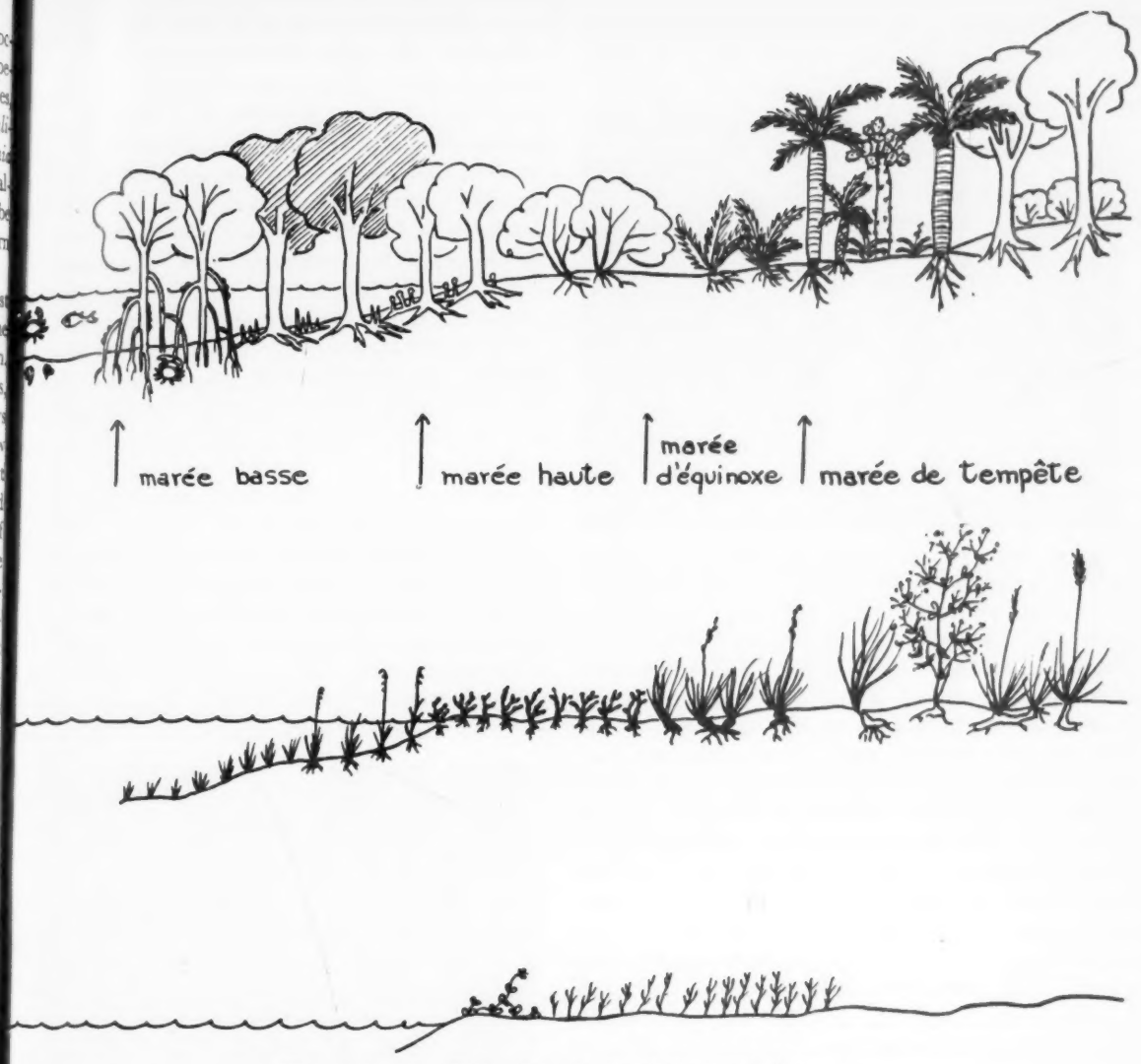
Grassy marshes also occur in salt and brackish water; for example, cordgrass (*Spartina brasiliensis*) will invade cutover mangrove. Rushes (*Scirpus* spp.) and tule (*Typha domingensis*) also cover extensive areas. The most considerable swamps, however, are fresh-water and involve *Cyperus giganteus*. The tall papyrus is often an indicator of rich Quaternary alluvium. Large tracts of this formation have been reclaimed through drainage. They have proved extremely valuable arable land, and the best sugar-cane plantations occupy such sites.

The river edges and borders of swamps are occupied by big shrubby *Mimosa* and *Vernonia* species and also by certain typical floodplain trees such as *Genippa americana* and *Symphonia globulifera*. The swamp forest dominated by *Tabebuia ovalifolia* used to be quite extensive, but has almost disappeared because its wood proved to be excellent for the fabrication of the sandals worn by a large number of town and city dwellers.

There is also extremely little lowland rain forest left. It is of the *laurilignosa* type of Rübel.[23] The tall trees are broad-leaved and mostly evergreen. Herbaceous epiphytes (bromeliads, ferns, orchids, mosses) are very abundant. This formation differs from the Amazonian rain forest by having few buttressed trees and comparatively few lianas.[7] It must formerly have occupied all the well-drained upland, and have occurred in various stages of succession. It consisted mainly of a fairly large number of species, none of which was quite dominant. The forester or naturalist from temperate regions is confused by the wealth of species. At first he can only hope to grasp the more obvious structural details of this compelling environment and is rather hard put to apply phytosociological methods. This can be done, however, as Veloso[27, 28] has shown in his analyses of complex climax communities, such as the *Lecythis ovata-Sickingia tinctoria* association.



The beach, showing the characteristic flora and fauna in each association.



The mangrove, illustrating characteristic associations.

As for less mature, or secondary, forests, they resemble those of higher latitudes. For instance, it seems that in some areas the *pau brasil* (*Caesalpinia echinata*) was especially abundant and even dominant. This may have been a subclimax type.

Since man's interference has degraded almost the entire upland today, many stages of succession may be observed, from the bare, raw, eroded land to the secondary forest. In general, after coffee and sugar-cane cultivation, pasture has set in and overgrazing has resulted in considerable stretches of shrubby fields. *Imperata brasiliensis* is a grass that will tolerate burning and even produce large quantities of tender green shoots after a fire. Many other grasses, both indigenous and introduced, are found in these pastures. With decrease in fertility and deterioration in structure of the soil, they are soon unable to compete with shrubs such as *Cordia curassavica* and *Baccharis schultzii*. Among the isolated trees that persist in open fields (as elms or pines will in eastern North America) the most remarkable is *ipé* (*Tecoma chrysotricha*), which loses its leaves in the winter and is covered in the spring with bright golden blossoms. A very tough low-growing palmetto (*Attalea indaya*) also takes over on open slopes and favors the return of the more heliophilous tree species, such as *Virola surinamensis*. These form a copse, comparable to our birch thickets; and presently the shade-requiring trees such as *Cabralea eichleriana* appear under their cover.

Orange orchards are frequent on the coastal plain, where they chiefly occupy the Tertiary low hills. Banana plantations are not so common and

Sugar cane growing on the eroded Tertiary outcrops of the coastal plain.

seem to be more successful on the slopes and in ravines. *Lantana camara* occurs as a tremendously aggressive weed under the bananas.

Human occupancy today has thoroughly modified the coastal plain, and various industries have transformed the landscape. Lumbering has almost ceased except in the mangrove, which is used for fuel by the fishermen. Fishing for mollusks, crustaceans, and fish largely remains an individual, uncoordinated enterprise. There is some agriculture of an extensive semi-industrial (Californian) type in the sugar-cane areas; otherwise, the people have small farms with low yields, and not much truck cropping is carried on. A cabin of bamboo and dried mud surrounded by a few rows of banana plants, two or three papaya and orange trees, and a small garden will maintain a family.

Rio de Janeiro, the largest city in Brazil, with its two million inhabitants, has grown out into the plain. It is still a city of small enterprises, with few large industries.

The Escarpment

Facing the sea and exposed to greater precipitation than the plain, most of the escarpment is too abrupt for extensive settlements. It is traversed by relatively few roads and has remained to this day largely a reserve for timber. Many areas still harbor virgin rain forest, with the tall *Cariniana excelsa, Cedrela fissilis,* and *Chorisia speciosa* trees covered with large, luxuriant bromeliads and hosts of tiny orchids and filmy hymenophylls. The deciduous *Chorisia* is an especially noteworthy element, as it would seem to register the slight monsoon effect of low winter precipitations. Lianas are also quite abundant, although not nearly so much so as in the Amazon Valley. Palms are frequent, especially in openings, as most of them are not true forest species. The famous *Syagrus weddelianus*, so common in the conservatories of the Northern Hemisphere, is indigenous here. Both tree and ground ferns are numerous, among the latter being several species of the interesting *Aneimia*. The general impression of the rain forest is one of greenness, moisture, depth, and freshness, but it is strangely silent as compared with a forest in Tennessee or southern Quebec in midsummer. Also, except for the flowers of *Chorisia,* the bracts of some of the bromeliads and an occasional large orchid, there is not much color.

On the contrary, the secondary forests, which now occupy large areas, are brilliant. They are often dominated by two species: *Cassia multiflora* var. *multijuga,* which produces big racemes of bright yellow flowers; and *Tibouchina estrellensis* with large purple blossoms. In late summer, from February to April, these trees bloom freely. Mingled with them or occurring in patches are several species of *Cecropia*, slender trees with bare trunks and

Sugar cane growing on the rich Quaternary alluvium of the coastal plain.

enormous fan-shaped leaves. One species roughly marks the 400-meter line above Rio, its hoary leaves glistening in the sun. These trees are a favorite home for ants and sloths. They also indicate poor soil conditions. Among the miserable bamboo huts on the hills above the great city there is one in each yard, as symbolic of poverty as the ailanthus "tree that grows in Brooklyn."

The streams are bordered by formations of a handsome semideciduous leguminous tree (*Piptadenia communis*) that responds very well to fluctuations in water level. Its bark is smooth and marked with white and gray patches like the skin of a snake. In its shade develop tall grasses and sedges (v.g. *Olyra* and *Scleria*) or sometimes low-growing herbs like *Lantana, Selaginella, Adiantopsis.* Near the roads, where man has disturbed the wet earth, *Impatiens sultani* (from Zanzibar via the greenhouses of Europe) has run wild: all the color phases of this beautiful plant, here a weed, occur in startling combinations. The stream bed occasionally broadens out into a *varzea,* and a cattail swamp is formed. Mixed with the *Typha domingensis* is the maltese cross (*Jussiaea*) and a tall daisy (*Erigeron maximus*), which seems to favor cool southern exposures.

On the sunny embankments are extensive tangles of the widely distributed tropical club moss (*Lycopodium cernuum*) with its curious nodding spikes; also the insipid tropical raspberry, *Rubus rosaefolius,* an invader from Asia.

Living in the cool shelter between the large leaves of the bromeliads are many kinds of tree frogs. Old Joaquino, who for many years accompanied the great Brazilian naturalist Adolpho Lutz on his excursions, knows them all by their cries.

The Inner Valleys

Between 400 and 800 meters, approximately at the level of the great central plateau, are high valleys running parallel to the coast ranges. Such is the Paraíba Valley, which can be taken as an example. These valleys were once forested and have been considerably modified by human occupancy. The rain forest that covered the upland was probably quite similar to that of the escarpment. Typical stands described by Veloso[27] were dominated by *Vochysia laurifolia, V. saldanhoi,* and several kinds of Lauraceae (*Ocotea, Nectandra, Urbanodendron, Acrodiclidium, Endlicheria*). The "palmito," *Euterpe edulis,* the myrtle, *Gomidesia spectabilis,* and the rubiaceous *Psychotria estrellana* are the most conspicuous plants in the small-tree and shrub layer.

Today, however, various subclimaxes are much more common. One of them is the *Cassia-Tibouchina* association already seen on the escarpment, with numerous *Euterpe edulis* and tree ferns (*Cyathea* and *Alsophila*) forming a small-tree layer, and *Psychotria* and *Begonia* at the shrub level. The latter are quite spectacular: their tall, reddish, succulent stems support broad clusters of white and pink flowers, and the dark-green dissected leaves are veined with scarlet and covered with brittle white scales. Other secondary forests described by Veloso are dominated by species of *Virola, Xylopia, Hortia, Sclerolobium, Cassia, Pisonia,* etc.[9]

An interesting point is the rather definite seasonal change that occurs in these forests. Veloso[27] has shown the maxima and minima of flowering and fruiting periods. Davis[10] has likewise investigated the phases of activity in mosquitoes, birds, and mammals, and divided the year into six distinct periods. He finds that animal populations are unlike in numbers, composition, and behavior in different forest types. Altogether, in fact, very little forest remains in these broad valleys outside the steep ravines and slopes, for most of the land has been cleared long ago and planted to coffee, and later to sugar cane. More recently it was given over to extensive pasturing. The present level of fertility is low, and relatively few of the original native plants have persisted. By far the most successful species is *Melinis minutiflora.* This African grass of extremely low requirements shows considerable resistance to drought and grazing. It is able to establish itself on the compact soils the animals have trampled and modeled into the typical scalariform relief characteristic the world over of exhausted hill pastures. It does not bear a considerable root system and actually thrives on the superficial layers of the soil. It turns out that this broad-leaved, sticky, profuse grass is fairly good fodder.[8] Its pink color and sweetish smell are quite characteristic, and in the minds of travelers and natives are as closely associated with that part of the Brazilian landscape as sagebrush with the western Great Plains of the United States or rockroses with the French Mediterranean maquis.

These pastures are soon invaded by a number of shrubs, most conspicuous among which is *Baccharis schultzii.*[27] The woody plants tend to open up and aerate the soil somewhat and prepare the way for other species with higher requirements. Bracken (*Pteridium aquilinum*) does not often invade open fields but is more successful on recently lumbered, and especially on recently burned, forest or scrub,

A hill in the Paraíba Valley, showing typical degradation from the original forest to pasture. *Melinis minutiflora*, the "molasses grass," dominates, although shrubs are now invading (*Baccharis schultzii, Cordia curassavica*). The scalariform microrelief is quite typical of such conditions the world over.

where the soil has remained relatively loose.[8] Another frequent invader of grassy fields is the beautiful orange-flowered vine *Pyrostegia venusta* (cultivated with loving care in our boreal greenhouses).

It is at this level that the soils are best known through scientific study. Setzer[26] has published a classification for the state of São Paulo and established interesting correlations with geological substratum, climate, and natural vegetation.

Part of the flat land is reclaimed marsh that probably used to harbor a tall, dense growth of grass and sedge (*Cortaderia, Eranthis, Cladium*). Now it is used for truck cropping, especially by the Japanese immigrants. Rice fields also are not uncommon.

Floods along the upper and middle course of the Paraíba are not rare, especially in summer, when the mountain ranges on either side get most of their rain and it pours downward, since forest no longer intercepts, evaporates, or stores the water. The shallow backwaters have many interesting plants: the large-flowered *Eichhornia azurea,* a pale-yellow *Hydrocleis,* a tangle of *Utricularia,* and *Myriophyllum.* Semiaquatic *Polygonum* and *Panicum* are on somewhat higher ground. Natural levees have long lines of fragile-looking, willowlike *Croton,* with beautiful leaves that turn red before they wither and fall.

The higher streams, not subjected to such extreme fluctuations as the Paraíba, are regularly lined with a zone of *Jussiaea,* which is followed by a belt of the tall coarse *Panicum virgatum.* A most remarkable plant, which more or less indicates the upper limits of flooding, is the garland flower (*Hedychium coronarium*). It has been introduced from Asia and is very abundant.

It is at this level that one finds the most extensive *Eucalyptus* plantations. These Australian trees make a tremendous growth under the Brazilian climate; but, although they flower and seed freely, they never seem to regenerate spontaneously as they do in New Zealand and California. The seedling is planted from nursery-germinated seed. After seven years' growth (to about 40 feet), it is cut; it grows again from the stump and is again harvested. This process can be repeated several times; however, the rate of growth slows down, and one must wait one year longer each time for lumbering. Many species of *Eucalyptus* have been tried; *E. saligna* and *E. robusta* seem to be the best adapted to the Paraíba and São Paulo areas.[2] *Eucalyptus* forests strongly contrast with natural communities:

the surface of the soil beneath the trees is quite dry. Almost no vegetation grows there, but the termites build up their conical mounds in large numbers. No epiphyte ever perches on the eucalypt's branches and trunks. The wood is used for such diverse purposes as papermaking and fuel for locomotives.

Several industrial enterprises have now become established on the sites of the former coffee-growing centers. Small towns long since in their decline, like Lorena, are undergoing a rejuvenation phase, and the whole economy of the Paraíba is affected.[24]

The Mountains

The Serra do Mar and the Serra da Mantiqueira have a more or less common and uniform economy but comprise several biological levels, or stories: the rain forest, the montane, the high-montane.

The differentiation that occurs with altitude is a most interesting one. It has been compared[7,8] with that of the deciduous Appalachian forest, as interpreted by Braun.[4] A large number of tree species are present in the optimum conditions of the lower levels. No single one seems to achieve actual dominance. At higher altitudes (the montane level), some of them drop out, and one or two of the remaining ones become dominant. Conspicuous changes in structure accompany this floristic shift: the forest becomes lower and somewhat more open. The layering also changes in both structure and composition. In fact, most of the species that assume greater ecological prominence with increased altitude are either present in the lower strata or in open habitats outside the forest itself at lower levels. Some of the small trees and tall shrubs of the rain forest even become dominants of the canopy in the elfin forest of the highest altitudes (*Roupala, Weinmannia, Clethra*).

The rain forest proper extends to above 1,000 meters, where a tropical montane forest supersedes it, and this reaches to about 2,000 meters. Above this, elfin forest prevails.[7] Actually, topographic irregularities somewhat obscure the basic zonation, especially in ravines. Lumbering and fire have also favored an upward movement of the tropical zone.[13] The rain forest retains the characters described above for inner valleys.

Montane level. The montane zone, since it does not harbor quite so many species of trees, is more uniform in appearance. The forest is frequently dominated by *Cabralea eichleriana,* and *Drimys winteri* is a characteristic small tree. *Psychotria* is represented by several shiny-leaved species. The trunks of the trees are partly covered, not only by mosses and leafy lichens, but also by large colonies of filmy ferns (*Hymenophyllum*), and of course by bromeliads. Some of these are small and tufted, with bluish-green, stiff, curved leaves and spikes of pink and purple flowers. These are the *Tillandsia* group. Others are very large, with leaves several

Erosion of the deforested hills in the Paraíba Valley.

A relict stand of Paraná pine (*Araucaria angustifolia*) at Campos da Bocaina (about 1,500 meters altitude). The undergrowth is largely *Podocarpus lambertii*.

inches broad, a deep green; at flowering time, they emit a large inflorescence clothed in crimson bracts (for instance, *Aechmea distichantha*). In the depths of their sheaths live numerous small creatures: insects, centipedes, spiders, tree frogs.

The montane forest is the home of many kinds of birds. The large-beaked toucan is heard more often than seen. Parrakeets fly in groups, chattering wildly, their green-and-blue plumage fluttering in the sunlight. A large mourning dove and several small, pert, lively warblers are also characteristic inhabitants. The *guaxe* spins its nest in oriole style from the tips of the branches of tall trees.

Various species of free-flowering, bright-purple *Tibouchina* replace one another at various altitudes. In openings, a tall lobeliad is quite common, its gigantic purple spike rising 15 feet from the ground. Dense clusters of bamboo have also filled in forest clearings, very effectively barring the way, whether they produce hard, close-growing canes or a tough mesh of garlands stretching in all directions.

These, and the enormous-leaved species of the *Rubiaceae*, the lovely purple-and-white-flowered *Brunfelsia*, and the many succulent and creeping begonias all disappear above 1,700 meters. But some of the tree ferns persist where the microclimate is tempered by a good tree cover. Such will be the case under the protection of the secondary forest of birch-white *Croton* with blood-red lichens on their slender trunks. Frost may form on the ground in fields and clearings but generally stops at the edge of the forest.

It is also at this level that relict *Araucaria angustifolia* forests are to be found; for instance, on Mount Itatiaia, at Campos da Bocaina, and Campos do Jordão. The great "pine" forests in the state of Paraná are found at 600–1,000 meters, whereas farther north, in the coast ranges, they are at 1,400–1,600 meters. Forming an understory to the *Araucaria* are *Podocarpus sellowii* and *P. lambertii*. The Paraná pine is a truly remarkable tree, unique in its outline. The presence of these isolated colonies in the coastal ranges can only be explained as a persistence from formerly more favorable conditions. There must have been a time (during the Pleistocene or perhaps more recently) when the present cool weather of Paraná extended far north of its modern confines. Later, the climate having warmed, the pines were able to maintain themselves only in a few privileged, unusually favorable spots. Among these, Campos do Jordão alone still has large stands of *Araucaria*;[11] at Campos da Bocaina and Itatiaia they have been ruthlessly lumbered.

The high-montane level. The highest part of the mountains has often been called the "campos

level," because of the prairie or steppe vegetation that prevails there. In fact, however, it was originally wooded. It is a great pity that so little remains of the primeval elfin forest, which is the easternmost extension in austral South America of a most interesting phytosociological complex that sweeps across New Guinea to New Zealand and appears at the montane level from south to north of the Andes and even penetrates Central America to Mexico. It has been the background for the evolution of many interesting genera, such as *Weinmannia, Podocarpus, Rapanea, Griselinia, Clethra,* and *Roupala.* In each one of the areas where the segregates of this old forest type appear, the epiphytes, the shrubs, and the herbs that it harbors show interesting local or regional affinities. For example, the bromeliads of the American areas are paralleled by *Collospermum* in New Zealand. It is interesting to find temperate (and presumed boreal) plants associated with these typically austral elements: *Anemone, Valeriana, Geranium.*

The forest has been extensively destroyed, however, mostly by fire, and is now replaced by more or less continuous grassland or tussockland. It has been and is being thoroughly overgrazed. Seasonal pasturing by transient herds (or transhumancy) was practiced to a considerable extent in the past and still is in some areas even today,[24] so that the present structure of vegetation is suggestive of steppe country, if this term could be used in an area of such pronounced relief.

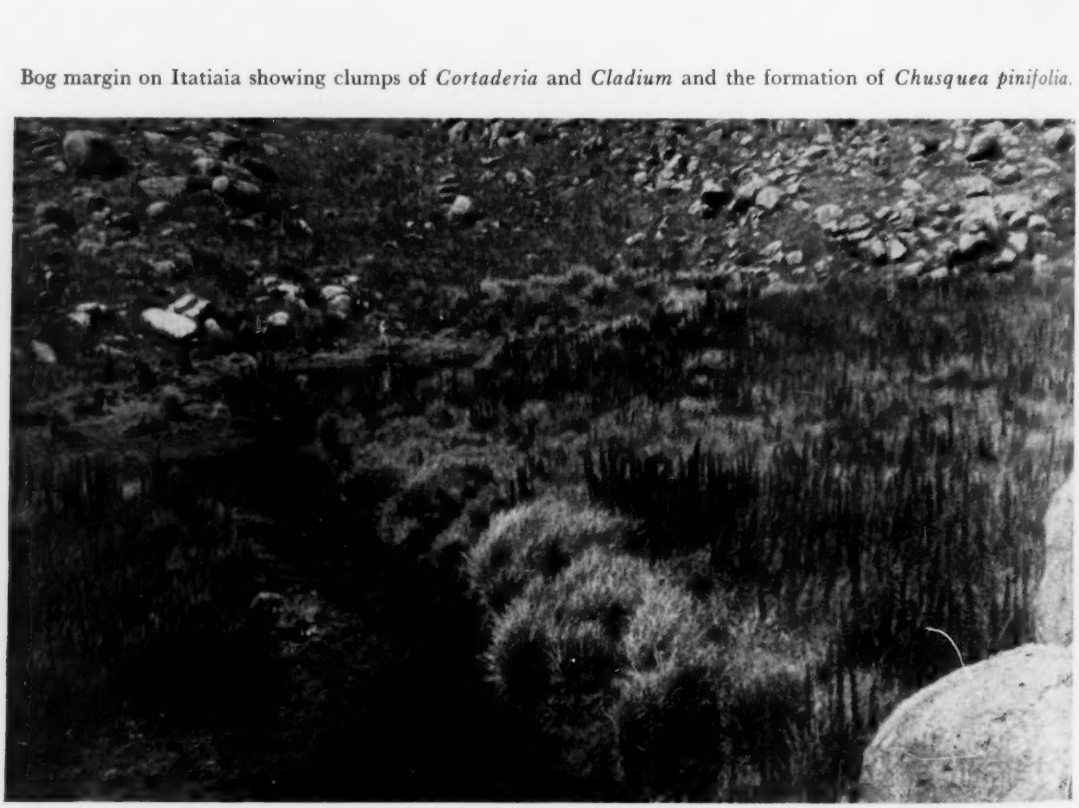
Above 2,000 meters, torrential rains, unevenly distributed, cause considerable erosion. The topography, with its large exposed outcrops and scattered boulders, is strongly reminiscent of recently glaciated terrain. Although continental Pleistocene glaciation does not appear to have extended so far north, geologists concede the possibility of local glaciation.[6] Blocked drainage permits the formation of bogs and the accumulation of sphagnum peat. The vegetation of these bogs is mostly of a graminoid type: *Cortaderia modesta* and *Cladium ensifolium* form enormous clumps several feet high, between which some ericaceous shrubs (*Gaultheria ferruginea, Gaylussaccia brasiliensis*) grow, together with *Xyris* and *Eriocaulon* and tall, coarse *Eryngium fluminense.* On their margins is a small bamboo (*Chusquea pinifolia*) and several woody composites that gradually close in.

Other areas, subjected to periodic flooding (*varzeas*), are swampy instead of boggy and have a lower-growing vegetation of small forms of the

A typical landscape at the "campos level" at Campos da Bocaina. What is left or what has regenerated of the forest is confined to ravines, whereas elsewhere lumbering, fire, and grazing have induced a steppelike vegetation on the dry, compacted soil.

The high-mountain areas of Itatiaia, strewn with boulders, strongly suggest glaciation.

Bog margin on Itatiaia showing clumps of *Cortaderia* and *Cladium* and the formation of *Chusquea pinifolia*.



A stand of *campo cerrado* in Pirassanunga, state of São Paulo.

Cyperaceae, out of which the tall scapes of large pink-flowered *Hippeastrum* grow.

Here, more than elsewhere, one can speculate on the biogeographical history of southeastern Brazil. Traces of climatic shifts are visible in the juxtaposition of heterogeneous elements, for many relict and endemic plants, animals, and communities are to be found at these high levels. The high-montane flora is rather more distinctive than that of the montane rain forest. Some species show Andean and subantarctic affinities, such as various small ferns (*Blechnum pennamarina*). Others are characteristic of the drier areas of the central Brazilian plateau. Among these, the most remarkable are certainly the various genera of the Melastomataceae. Almost all of them are on the drier, eroded sites, being small, stiff, more or less ericoid shrubs with bright-pink or purple blossoms. Many boreal genera—for instance *Danthonia, Achillea, Fragaria, Ranunculus,* and *Cladonia*—form part of the extensive communities that occupy deeper soils on the open or exposed sites. It is always interesting to note among these the admixture of such narrowly local species of tropical origin as the endemic *Congdonia coerulea,* a delicate sky-blue-flowered herb.

Some of the dense, low-growing swards are quite typically alpine in appearance, having developed good, well-drained humus in the root layer of the grasses. A dwarf form of *Chusquea* is mixed with *Danthonia montana* and a *Sisyrinchium.* The pioneer stages on rocks include patches of *Cetraria* and *Cladonia* lichens and *Gaultheria.*

Beyond the coastal ranges extends the great plateau of central Brazil. Much of it is occupied by the *campo cerrado,* a savanna type of vegetation. In fact, some outliers of savanna occur in the state of São Paulo, within the coastal range, in the inner valleys. These disjunct *campos cerrados* can be considered as preclimax to present-day rain-forest vegetation. They exhibit a most peculiar layering: small, open trees, interspersed with tall grasses and very low, incredibly deep-rooted shrubs.[21, 22]

Southeastern Brazil has a rich flora and fauna, which are comparatively unexplored. Modern concepts of taxonomy have not as yet been applied to them. The problem of sympatric speciation as it appears in *Begonia, Tibouchina, Baccharis, Psychotria,* and many other groups calls for mass collections, cytological counts, and ecological mensurations, not to mention experimental hybridization. The communities are even less well known. It can hardly be said, as yet, what existing phytosociological methods will yield in the study of the Brazilian vegetation. Experiments in the Belgian Congo, India, Senegal, Central America, and Australia

have shown the necessity for some modification of ecological concepts and methods as they have developed in moist-temperate countries. This area offers many wonderful opportunities to make just such a test. Veloso's pioneering efforts in this direction should lead to many more studies of the same kind and further experimentation with methods.

In autecology, Rawitscher[19] has blazed the trail and provided Brazilian workers with an excellent general review of environmental factors as they affect the plant organism.

There is a fine tradition for the natural sciences in Brazil, one which originated in the works of European writers but which has now been fully assumed by the Brazilians themselves.

DRAWINGS are from Zonation et Succession sur la Restinga de Rio de Janeiro (DANSEREAU, P. *Revue Canadienne de Biologie*, 1947, **6**, 448–77), and are used by permission.

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CHOICE

This it is to be mortal:
Dreading the final breath
Or gallantly waving the banner,
The gaunt grey standard of death.

Never doubt you must choose, then,
This side or that espouse,
Though victor shall with the vanquished
Sleep in the same strict house!

VIRGINIA SCOTT MINER

The Organization of Government Science in the United Kingdom

W. A. MACFARLANE

Formerly Director of Fuel Efficiency, British Ministry of Fuel and Power, the author (Ph.D., California, 1934) came to the United States in 1948 to serve as scientific attaché to the British Embassy and as Director of the United Kingdom Scientific Mission in North America. His article is based on an address given at the Academy Conference, New York Meeting of the AAAS.

World War I provides the most convenient starting point for the story of government science in Great Britain. Although the National Physical Laboratory had been founded at the turn of the century, and the Geological Survey long before that, it was the war that first made evident the effect science might have on the industrial capacity of the country, and indeed on every facet of national health and wealth.

In 1916, therefore, the Department of Scientific and Industrial Research was founded, not as a war measure, but as a piece of farsighted planning for the reconstruction period. In 1920, an existing Medical Research Committee was reconstituted as the Medical Research Council. In 1931 the third body, the Agricultural Research Council, was established. We must jump, for a moment, to World War II for the final step in the organization of government science. This was the appointment of an Advisory Council in Scientific Policy to survey the whole field of civil science, to consider broad matters of policy that might affect science as a whole, not just its application in agriculture, medicine, or industry. This council is proving of immense importance, and is the body to which many of the problems of organization that arise are referred.

First, then, I should like to pick the D.S.I.R. as the department I know best, and discuss the philosophy with which its founders were imbued. Here I must acknowledge that I am drawing heavily on the excellent account given by Sir Edward Appleton in his May (1949) lecture to the Institute of Metals.

The problems which the department had to face in its early years were indeed difficult ones. British industry was then frankly skeptical about the help it could get from science. There were few laboratories, and the number of men of scientific training leaving our universities was only about a tenth of what it is today. The founders of D.S.I.R. might have concentrated the available effort upon a few particularly urgent problems. Instead, however, they decided to proceed, to quote their first report, "by a gradual and systematic attack upon a wide and carefully selected front." This front, the council soon saw, must cover three main activities: First, the encouragement of fundamental research at the universities and the training there of research workers to meet the needs of laboratories of all kinds; second, the encouragement of research in industry, particularly through the development of the cooperative spirit, both in industry itself and between industry and the department; and, third, the promotion of research to meet the requirements of government and the needs of the community.

Although, in fact, the council addressed itself first to the organization of industrial research, because the members felt the paramount importance of arousing and securing the interest of industry in the application of science, they were, nevertheless, under no misapprehension as to the relation between fundamental science and applied science. They saw in fundamental science the source of new

ideas from which the great industrial advances sprang. As J. J. Thomson once said, "Pure science is the seed of applied science, and to neglect pure science is like spending a very large amount on manuring and ploughing the land and then omitting to sow any seed."

The council realized that its view on fundamental science was neither understood nor appreciated by the industry of that day. In their contacts with industry council members were left in no doubt that what manufacturers wanted was quick results, and that most of them were not interested in research that would not produce results within a year. What, therefore, the founders of the D.S.I.R. set out to do was to educate industry to understand what research really was and to appreciate the value of the scientific approach to its everyday problems. In embarking on this policy the council clearly recognized that cooperative effort was no substitute for research by the firms themselves, or, taking the short view, even for research carried out on behalf of industry in existing laboratories.

Though the council decided to plan to encourage research in industry itself along cooperative lines, it nevertheless recognized that there were many other fields of work which called for independent action by the state. There was, for example, the National Physical Laboratory, for which the department had become responsible, whose work on units, standards of measurement, and on the determination of physical constants and data of all kinds was fundamental to all industrial activity. There was also the question of building, important not only as a capital charge on every industry, but also because of its effect on better housing. The council therefore decided that all these matters could best be dealt with by research organizations, supported by research stations, under the department's direct control, the results of whose work would be available for all, and whose facilities would provide a central scientific service for government. Thus in a few years the founders of D.S.I.R. evolved a plan or, perhaps better, a philosophy, for the encouragement and promotion of research which has been broadly followed ever since.

Let us, then, turn the pages of history rapidly and see to what extent this philosophy has been put into practice. We can distinguish two phases: the interwar years when progress was as steady as economic blizzards allowed, and the effects of World War II. This war, again, had an effect on science, which we may hope will prove not only more durable but more beneficial than the effect of science on war. The need for an increased scientific effort to solve the problems of peace was again brought into sharp focus.

The first of D.S.I.R.'s activities, the encouragement of fundamental research at universities, takes two forms: the provision of maintenance grants for graduates, and of funds for the purchase of equipment, etc., for specific research programs. In the interwar years D.S.I.R. helped to finance Kapitza's work in the production of intense magnetic fields, Bragg's on the application of X-ray analysis in industry, and Appleton's on the propagation of radio waves through the upper atmosphere, to mention but three distinguished examples. The total of these annual grants for research was very modest before the war, amounting in the financial year 1938–39 to just over £26,000 in all. This year, between half and three quarters of a million pounds sterling is to be allocated from all sources, and the *number* of maintenance grants to students and senior workers has been increased between three- and fourfold.

Though the figures I have just quoted represent a considerable increase in D.S.I.R.'s help to university research, they may well seem modest in comparison with U. S. assistance in the same field, since, I understand, the Office of Naval Research alone has a budget of something like $20,000,000, most of which is expended on university contracts. So I should emphasize that grants for particular research projects are, in the United Kingdom, a subsidiary method of government assistance to the universities, and not the main one.

Next, let us turn to the efforts of D.S.I.R. to encourage British industry to carry out cooperative research. Since the objective in launching this research association movement was to increase industries' own appreciation of the value of research, the part played by D.S.I.R. has been to give advice and financial assistance, but to interfere as little as possible with the affairs of the association or its conduct of research. Thus, each research association is a body governed by a council consisting mainly of members drawn from the industry. This council acts as does the board of directors in a private company in determining the policy of the research association, in appointing the director of research and his staff, and in determining the research program.

The way in which these research associations draw their income from industry varies a good deal. Those that were formed early in the history of the movement generally rely on voluntary subscriptions, which are expected to vary according

to the size of the firm but which generally have a very modest minimum. More recently some of the associations have assessed their members according to some index of each firm's output.

D.S.I.R.'s contribution is generally related to the industrial income, but it varies in proportion in different cases. On the average it is roughly 50 per cent of the industrial income. Sometimes, however, it may be as high as 100 per cent, particularly with newly formed associations, and exceptionally it has exceeded the contribution from industry. Experience has shown that an association whose income does not exceed £25,000 a year cannot now undertake more than a few of the activities that it should. Sometimes the smaller industries can be advised to seek membership in one of the larger research associations. In other cases industries that are related industrially or scientificially can form a research association to serve their group.

Up to the war about twenty industries had formed research associations of this kind. Between 1943 and 1948 twenty-one additional research associations were formed, so that the coverage of industry is now pretty well complete. The grants made by D.S.I.R. to the research associations in the financial year 1938–39 were just over £170,000. In 1947–48 they had risen to just under £1,000,000, an increase of over fivefold.

The success of a research association is not to be judged solely by the products of its own laboratory. Insofar as it is able to convince the firms in the industry it serves of the value of scientific research, those firms will take the next step and set up their own laboratories to solve their own particular problems. There is no doubt, of course, that the better a firm has equipped itself with scientific staff and laboratories of its own, the more advantage it gains from its contribution to the research association. For example, since the research association has responsibilities to all firms in the industry, it cannot undertake work especially for one firm. Therefore, its work will lie mainly in general problems affecting the industry as a whole or large sections of it; the results will obviously be of most value to the firm that is well equipped to work out for itself the application of a new discovery to its own products.

In this respect, the research association differs entirely in character from the great industrial research institutions such as Mellon and Battelle, in the United States. If the organization of one is horizontal, in that it serves all firms in one industry, the organization of the other is vertical, in that it must spread its contracts over a large number of industries and be careful that it is not working for two firms in the same trade on two closely related problems. The absence of an institution on the Mellon model in Great Britain, until recently, has been felt to be a gap in our equipment, since obviously it has many great advantages, particularly in its flexibility. It makes it possible to get research work started on a new project without waiting to recruit staff and perhaps to build a new laboratory. We are, therefore, all watching with interest the progress of the first organizations of this character to be founded in Great Britain—the Fulmer Research Institute, which is specializing in the metallurgy of the light metals, and Sondes Place for general chemical work.

It has been argued, too, that institutes like Mellon and Battelle provide the answer to the research problem of the small firm which has not the funds to set up a laboratory and pay a staff of its own. I gather that this problem, however, which is a most serious one for us in Great Britain, has perhaps not been entirely solved even by these institutes, since a great proportion of their facilities is occupied with work for the larger corporations who, despite the fact that they have their own research staffs, or perhaps because of it, appreciate the advantages of farming out some of their problems as well.

The research associations in Great Britain have given much thought to the problem of serving their smaller member-firms. One of the main methods they have adopted is to set up as comprehensive an information service as possible. It is the general rule for a research association to provide its members with a specialized abstracting service, in which all the new papers relevant to the particular industry are briefly noted. When one contemplates the size of the monthly issues of the more general abstracting services, such as *Chemical Abstracts,* admirable though they are, one realizes the advantages of this selective service to the small firm with limited staff.

More recently, many of the research associations have appointed liaison officers who divide their time between the laboratories and visits to member-firms. Although it is not intended that these men should go "trouble shooting," their visits often prove very valuable in pointing out to a firm how work that the association has done bears on its particular problem. They are of value, too, because the visiting scientists will see for themselves the problems that are worrying the industry, and so will bring back to the association's headquarters ideas that can be incorporated in the research program to make it fit more closely the needs of the industry.

Now let me turn to the work at D.S.I.R.'s own research stations—that is to say, those that are staffed by scientific civil servants, and the funds for which are wholly provided by government. The National Physical Laboratory and the Geological Survey were brought into D.S.I.R. early in its history. Then there were added the Fuel Research Station, the Building Research Station, the Chemical Research Laboratory, the Forest Products Research Station, and laboratories for food and road investigation and for the study of water pollution and pest infestation.

Since the war there have been several additions to this list; namely, organizations for fire research, mechanical engineering research, and for the study of loose boundary hydraulics. The Mechanical Engineering Research Organization will, in time, take over a substantial part of the engineering work carried on at the National Physical Laboratory; also, a separate organization for the laboratory's radio research has been formed.

The expansion of all these laboratories to the scale now considered desirable is delayed by shortages of manpower and equipment and by building difficulties. Nonetheless, once again there has been a considerable increase in their budget as compared with prewar. The expenditure on this group of laboratories, quite apart from that in the headquarters offices of D.S.I.R., was just under £700,000 in 1938–39 and is now well over £2,000,000. Of course, some part of that increase must be set off against the fall in purchasing power of the pound.

It will have been noticed that there is one fundamental difference in the organization of government science in the United Kingdom and in the United States. Because D.S.I.R. and its sister bodies, the Medical Research Council and the Agricultural Research Council, were founded relatively early in the history of government science, they formed between them a central scientific service for government, responsible to a single cabinet minister. In the United States you have followed the opposite path and attached each scientific organization to the pertinent executive department. Agricultural research, for example, is concentrated in the Department of Agriculture, the Bureau of Mines in the Department of the Interior, and so on.

There are indeed parallels to the U. S. form of organization in Great Britain. The Post Office, for example, which with us is responsible for the telephone and telegraph services as well as for the delivery of mail, has always maintained its own research organization. But, after all, the Post Office more nearly approaches in function a commercial concern than a normal government department. The service departments, which are excluded from this survey, each maintain their own separate research organizations, although there is provision for coordination of their programs at the top.

With these partial exceptions, the plan of centralizing government research in special departments existing for that purpose held sway generally in Great Britain before World War II. The advisability of this form of organization has recently been reviewed, and the considerations put forward for and against centralization may be of interest. During the past ten years the civil departments have found that they have become increasingly concerned with technical matters in their day-to-day business. Inevitably, therefore, the question arose as to whether some of the research stations which D.S.I.R. had fathered should not be transferred to the executive departments of government. In favor of this proposal, it was argued that wartime experience had shown that the best help could be obtained from science only if the scientist were brought into the innermost councils. This was more likely to take place in time of peace if the research organization were part and parcel of the executive department than if it lay outside it.

Against this view, and in favor of retaining the centralized structure of government science, it was argued that there was more danger of interference with scientific programs if the research organization was part of the executive department. Many scientific programs, of course, take months or years to complete, and pressure might be brought to bear on research workers to leave their longer-range work in order to solve the problem that was worrying the administrator on any particular day. Then it was hinted that, if the time came when government expenditure had to be slashed, the budget for research might suffer more if it lay in the hands of the executive department, which might have many other directions in which to spend its money, rather than in those of D.S.I.R., which had to fight for appropriations for science and science alone. This is an argument which is, I know, not applicable to the United States, where the machinery of government finance is somewhat different than our own. But it did carry considerable weight in Great Britain.

Such arguments, and many others, were no doubt considered when the question was referred to the Advisory Council on the Scientific Policy. Their final conclusions were: First, that the existing structure, whereby most of the basic research was carried out by the D.S.I.R. and its two sister organizations, should not be upset; second, however,

that the executive departments should be responsible for identifying the problems required in research and settling their order of priority; third, that the responsibility for application of results of the research, what might be broadly described as development work, should rest primarily with the executive departments; and, fourth, that the D.S.I.R. laboratories should, as in the past, be free to initiate background research where they thought fit, free from all considerations of day-to-day expediency. As a consequence of these recommendations, however, the council urged that those executive departments which had not hitherto appointed scientific advisors, at a level which permitted technical information and advice to be brought to bear in the formulation of policy, should immediately do so.

It is too early yet to say whether this division of functions will prove satisfactory. But we may be optimistic that it will, for on the one hand it preserves the liberty of action of the research worker, and on the other hand it provides for the participation of the scientist in the executive department in the formulation of policy. Further, it clearly allocates responsibility for basic research in D.S.I.R. and for development work in the executive departments, a division which corresponds with the general observation that people with different habits of mind, if not different qualifications, are required for the two jobs.

Another reason for optimism is that these principles of organization broadly follow those adopted for agricultural research in the thirties. The executive department in England and Wales is the Ministry of Agriculture and Fisheries, whereas in Scotland there is a separate Department of Agriculture. When the Agricultural Research Council was formed in 1931, there were already laboratories in existence under the direct control of the executive departments, mainly for the purpose of dealing with notifiable foot-and-mouth disease, anthrax diseases such as swine fever, etc.

The technical work of the Departments of Agriculture has been greatly extended since 1931, despite the simultaneous growth of the A.R.C. The departments have concerned themselves primarily with the application of scientific methods in agricultural practice, the A.R.C. with basic research. The division of responsibility can perhaps be most quickly illustrated by listing the names of some of the research institutions. Among those under the direction of the executive departments are the Horticultural Research Station, the Glasshouse Experimental and Research Station, the National Institute for Research in Dairying, and the Institute of Agricultural Engineering. The more basic nature of the work in the Agricultural Research Council's laboratories is reflected in such titles as the Plant Virus Research Unit, the Insect Physiology Unit, the Institute of Animal Physiology, and so on. Naturally, such a dual organization could be maintained only as long as there was close liaison between them and a free flow of ideas between those undertaking basic research and those responsible for putting the results into practice.

There are at the present time twenty-seven government Agricultural Research Institutions in Great Britain, and today agricultural research is almost wholly financed by the state. The Agricultural Research Council maintains systems for grants-in-aid of special research at universities and for research studentships that are similar to those for D.S.I.R. The expenditure for which this Agricultural Research Council was responsible in 1948–49 amounted to just over £500,000. Adding in the budgets of the Executive Departments, the total exceeded £2,000,000.

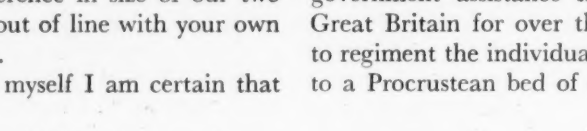
I have shamefully treated the Medical Research Council by leaving so little space to refer to its important work. I must content myself with pointing to two particulars in which this organization differs from that of the A.R.C. First, although it maintains its own central laboratories at the National Institute for Medical Research at Hampstead, a much greater proportion of the work is carried out by units in the great teaching hospitals, where clinical material is of course much more readily available. There are now about forty of these establishments in all. The second point of difference from agriculture is that, whereas the M.R.C. budget for 1948–49 amounted to over £1,000,000, this represents only a part of the funds available in the United Kingdom for the support of medical research. In addition to the substantial resources of the universities and hospitals, there are many independent institutions, such as the Nuffield Foundation, the Wellcome Foundation, and the Cancer Research Fund, which carry out large research programs.

Let me now try to sum up this necessarily incomplete account of government participation in research. We must, I think, judge any such project by its scope, its organization, and its results. The last criterion, the results, I have deliberately left aside, although it is, of course, the most important one. It would require a separate, and a longer, discussion to summarize the research work that these organizations have carried out. As to scope, government expenditure on research in the United

Kingdom is now running at the rate of about £10,000,000 a year for civil research and £60,000,000 for defense research. Much though we may as individuals regret this concentration in both our countries on scientific work for military purposes, we must no doubt accept it as inevitable in the present state of the world.

This total annual expenditure of £70,000,000 you will inevitably wish expressed in more familiar currency. I have deliberately refrained from translating pounds into dollars as I went along, first, because I find it hard to multiply by 2.8 and, second, because I decline to believe that the value of British research was suddenly reduced by a third sometime last September. I suggest that the purchasing power of the pound for research will be more accurately expressed by translation at the old rate of exchange. Total government support for research in the United Kingdom may therefore be taken as about $280,000,000 a year, which, bearing in mind the difference in size of our two countries, is perhaps not out of line with your own government's expenditure.

As to organization, for myself I am certain that there is no single and final solution to such problems as maintaining the right balance between fundamental and applied research, between the advantages of centralizing government science and spreading it among executive departments, between letting scientists follow their own inclinations and mobilizing large teams to solve immediate questions. The answers must depend on the circumstances of the times, war or peace, prosperity or poverty. It may be because we in Great Britain have escaped the rigors of a written Constitution that we attach great importance to flexibility in organization. If you could look at the terms of reference of the councils which advise British government departments on research, you would find in many of them the phrase "to keep under review." And, as a further example of the need of adaptation to a changing world, a survey is just now being made of the functions and organization of D.S.I.R. This, at least, can be claimed: that government assistance has been administered in Great Britain for over thirty years without trying to regiment the individual scientist, or to fit science to a Procrustean bed of policy.



BENJAMIN DISRAELI, in a late speech at Clasgow, made the significant admission that the revolutions of science within the last fifty years have had "much more effect" in moulding the world than any political causes; and that "they have changed the position and prospects of mankind more than all the conquests, and all the codes, and all the legislators that ever lived!"—*The Popular Science Monthly*, 1873–4, **4**, 640.

Pharmacology Today

J. H. WILLS

Dr. Wills (Ph.D., Rochester, 1940) is in the Pharmacology Section of the Medical Division, Army Chemical Center. He did postdoctoral research at Harvard Medical School and taught pharmacology at the Universities of Rochester and Tennessee. He was a member of the Rochester Desert Unit doing wartime research on the physiological aspects of desert warfare, and later worked on the Manhattan Project.

FOR so long as man has applied or administered to himself various substances for the relief of pain or sickness there has been a kind of study of drugs, or pharmacology. It is probable that at the earliest times drugs were regarded simply as aids to incantations for the exorcism of disease demons. Gradually there developed in parallel to this quasi-religious therapeutics a secular, empirical system of treatment. For example, it is thought that in Mesopotamia by the time of the Akkadian King Naramsin (about 2800 B. C.) internists had been separated into religious practitioners, or exorcists, and secular physicians. The latter used drugs of herbal origin for the most part.

Lists of substances thought to be useful in the treatment of disease grew longer as man's experience with natural products became wider, so that when Pedanius Dioscorides made his great compendium of drugs in the middle of the first century A. D. there were some 600 remedies which seemed worthy of mention. During the Middle Ages many new substances were introduced for use as drugs, largely by the Arabs. Until the latter part of the seventeenth century, when scientific therapeutics founded on experiment may be said to have started, there was no method except the empirical one for selecting from the multitude of drugs listed in various compendia those that are truly useful.

During the eighteenth century there was a gradual expansion of use of the experimental method in studying the action of drugs. François Magendie (1783–1855) first made the experimental approach pre-eminent in medical science by refusing to place any credence in statements that had not been confirmed by experiment. Despite this promising start in France, the experimental study of drug action was initiated largely in the Germanic countries. Rudolph Buchheim (1820–79) set up the first exclusively pharmacological laboratory, at the University of Dorpat, in 1850. His *Lehrbuch der Arzneimittellehre* (1856) was the first book to group drugs according to their action on organs and tissues rather than according to their therapeutic uses.

Modern, or experimental, pharmacology started as a specialized branch of physiology and physiological chemistry. It is still true that pharmacology as a science has no unique technique of its own; its methods are those used in biochemistry, biophysics, and physiology. (There is one technical procedure which has been developed to the point of being almost a specialized technique; this is the process of bioassay, which will be considered later in somewhat more detail.)

From the historical standpoint, experimental pharmacology may be said to have developed the following types of study in temporal sequence:

1. Determination of the quantitative relationships between dose or concentration of a drug and its action on organs or systems in the animal body.
2. Identification of the major site or sites of action of drugs in the body.
3. Investigation of the relation between the chemical constitution of substances and their action.
4. Determination of the absorbabilities of drugs, their distribution within the body, the routes and amounts of their excretions, and their fate within the body.
5. Investigation of the intimate, biochemical mechanisms of drug action.

Although these various kinds of study have developed roughly in the temporal order given above, most of them are considered now to be necessary for complete characterization of the action of a given drug. One begins usually by studying the gross action and toxicity of a new compound. This investigation yields clues as to what should then be studied to determine the site and mechanism of action of the drug and to elucidate the distribution and fate of the compound within the body. The relation between chemical constitution and action can be studied, of course, only if two or more substances of a homologous series are available.

Corresponding roughly to the various steps enumerated for the complete study of the action of a compound in the animal body are several

general assumptions that are fundamental in modern pharmacology:

1. Drug action is a definite function of dosage, or concentration, of the drug bathing cells.
2. Drug effects in the animal body are produced by alterations in the normal physiological mechanisms of the body.
3. Within a series of homologous compounds there will be some orderly progression of activity as the series is ascended.
4. The duration and intensity of drug action depend upon the balance between the rates of (*a*) absorption into the body, (*b*) reaction with crucial cellular constituents, and (*c*) removal from the body.
5. Localization of drug action to a definite structure of the body depends upon reaction between the drug and some component or components of the tissue or organ.
6. Drugs introduced into the body may be altered there so as to be either less or more efficacious.
7. Drug action depends upon an effect of the drug upon the metabolic system of the tissue or organ affected.

In an article of this length it is impossible to discuss fully all the points previously listed and to consider the latest developments in each class of drugs. All that will be attempted is illustration and discussion of the recent developments in some fields of pharmacology which are most active at the present time.

Quantitative pharmacology. This branch of pharmacology deals with the relationship between dose, or concentration, of a drug and the characteristic action of the drug. When the magnitude of some drug effect is plotted as a function of the dose, one of two general types of curve may be obtained (Fig. 1). The curve illustrated in Figure 1*A* is called a graded action curve, and that shown in Figure 1*B* is called an all-or-none curve. As shown in Figure 1*A*, graded action curves fall into two general categories: those showing a linear relationship between the dosage of a drug and its effect, and those displaying a nonlinear relationship. The group of nonlinear graded action curves has been separated by A. J. Clark into hyperbolic, exponential, and power types. It is the job of the quantitative pharmacologist to obtain and express in some way these various types of dose-action curves.

The method of expression that has been standardized for such studies is the statement of the dose of the drug required to produce some effect in half of the experimental animals treated with that dose. This quantity is denominated the ED50; if the end result of administration of the drug happens to be death, the dose lethal to half the animals is stated and is denominated the LD50. It can

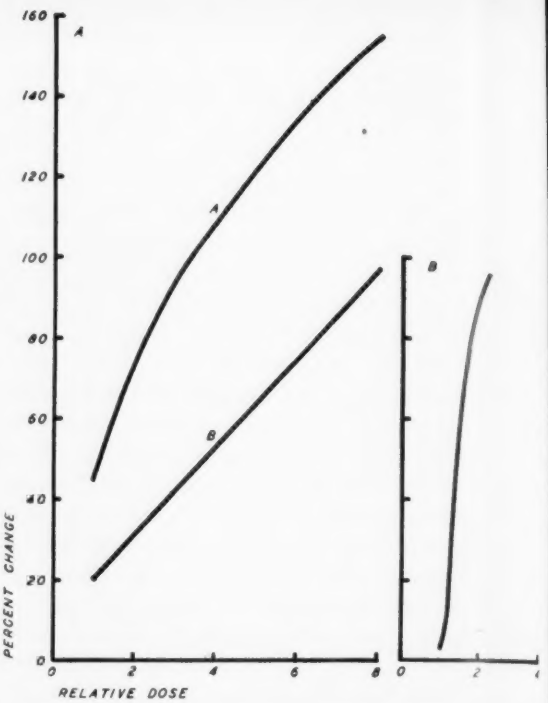


FIG. 1. Dose-effect curves. *A*, graded action: A, effect of ethyl urethane on per cent reduction in reflex response of the decapitated cat (from data of van Leeuwen); B, effect of epinephrine on per cent increase in contraction of cat nictitating membrane (from data of Rosenblueth). *B*, all-or-nothing action: mortality of frogs injected with varying doses of digitalis (from data of Behrens).

be seen that in the case of a linear dose-action curve relatively few points on the curve need to be determined to allow accurate interpolation, or extrapolation, of the ED50. The situation with the nonlinear graded action curves and with the all-or-none type of curve is very different, however. Here, reasonably accurate estimation of the ED50, or the LD50, would require that points in close juxtaposition to the 50 per cent dose be studied. This could be a very tedious process, especially with a steep curve of the all-or-none type. For this reason, other methods of treating the data of the nonlinear curves have been sought.

It has been found advantageous to transform mathematically the experimental data in some way, the aim being to find a transformation that will allow the data to be plotted linearly. Probably the most widely used of these transformations is the probit-log dose plot. In this procedure the percentage of response to the drug is expressed in multiples of the standard deviation, by use of a table worked out by C. I. Bliss, and is plotted against the logarithm of the dose of drug. The effect of this transformation on data is shown graphically in Figure 2; the linearity of the probit-log

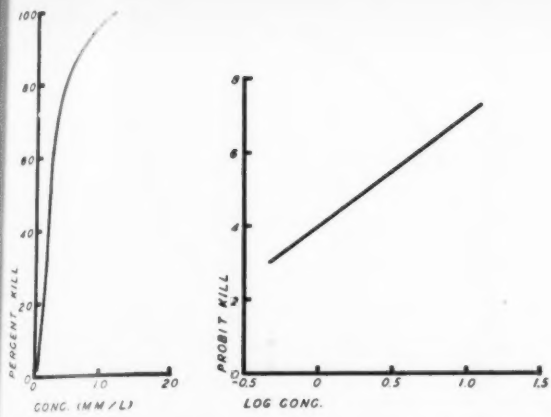


FIG. 2. All-or-nothing dose-effect curves. Left, effect of nicotine spray on survival of *Aphis rumicis* (from data of Tattersfield and Gimingham); right, probit-log dose plot of same data.

dose plot allows interpolation or extrapolation of the ED50 (corresponding to probit 5.0) from relatively few points.

Even with the use of the probit-log dose transformation, a comparatively large number of animals must be run, because for each point there must be enough animals to yield a reliable percentage. Running all these animals requires more time than it may be expedient always to spend. For this reason various workers have tried to devise methods for determining the approximate ED50, or LD50, with small numbers of animals. A widely used method of this sort is that of Deichmann and Le Blanc, in which a series of 6 or fewer animals is used. Each animal in the series is injected with a dose of drug which is either 50 per cent greater or less than that given to the previous animal until a dose is found which produces an action, although the next lowest dose does not. This approximate ED50 has been found to agree within an average of 10 per cent with the ED50 estimated by the more laborious Bliss method.

In addition to studying the dose-effect curves, quantitative pharmacologists may study the time-concentration and the time-effect characteristics of drug action. In each case a group of curves is obtained. It has been found that three general types of time-concentration curves occur (Fig. 3), fitting the equations:

$$K = Ct \qquad (1)$$

$$K = C^n t \qquad (2)$$

$$K = (C - k_1)(t - k_2) \qquad (3)$$

Here K, k, and n are constants, C is the concentration of the drug, and t is the time required for that concentration to have some standard action. These various kinds of curves have been interpreted as indicating processes in which the rate of drug action is conditioned respectively by diffusion, by adsorption on the cell surface, or by some all-or-none type of effect. Such interpretations assume that the appearance of some given effect signals the uptake by the affected structure of a standard quantity of drug. This assumption appears possibly to be untrue, so that physicochemical interpretations of time-concentration curves must be regarded as very tentative.

The time-action curves of drug action resemble the concentration-action ones in that they may be either graded or all-or-none. The all-or-none time-action curves, like the corresponding dose-action curves, have a sigmoid shape. This is to be expected because of the dispersion in duration of the periods required for the drug to penetrate to all units of the affected structure. Three types of time-action curves of graded nature are shown in Figure 4. The nicotine curve, by rising to an apparently steady maximum, indicates that this drug may combine reversibly with some constituent of the muscle. The fact that the curve for caffeine goes through a maximum suggests that this compound combines irreversibly with some important cellular constituent, producing finally frank injury to the muscle. The very rapid and transient effect of KCl on the muscle may indicate that the salt produces some temporary alteration in the physicochemical

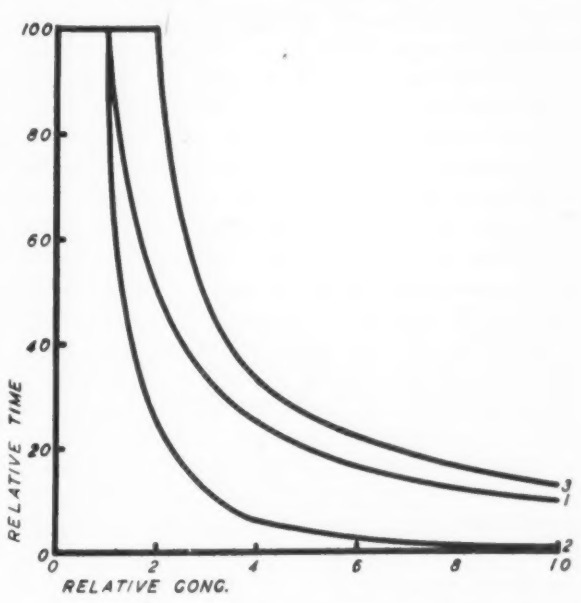


FIG. 3. Time-concentration curves, plotted from the text equations. The identifying integers refer to the equation numbers in the text. In all cases, K is assumed to be 100. In equation 2, n is assigned the value 2; in equation 3, k_1 and k_2 are given the values 1 and 2, respectively.

properties of the cell membrane. Attempts to analyze the time-action curves in terms of more precise physicochemical mechanisms of reaction are probably fruitless because of the very complex organization of the cell, which in turn renders it possible that drug reactions with cells involve chains of reactions rather than single, discrete chemical processes.

Biological assay. Bioassayists use the methods of quantitative pharmacologists, being concerned primarily with dose-action curves. Biological assay has as its aim the comparison of some drug sample of known character but unknown potency with another sample of the same drug having a known potency. This aim is implemented by administering three or more dose levels of each drug sample to groups of test animals. The probit-log dose plots of the results should yield two straight lines of the same slope. If this condition is not satisfied, the assayist must consider the assay invalid because of some technical error or because of unequal sensitivity to the drug of the subgroups of animals receiving the various doses. One standard method for estimating the validity of an assay is to compute the composite slope for both the standard and the unknown curves. Then the statistic known as "chi-square" is calculated for the composite slope, using one degree of freedom. The value of chi-square indicates whether the two lines deviate significantly from parallelism.

From what has been said, it is apparent that the cardinal principle of bioassay is that the measurements must be comparative. The groups of animals to be injected with the various doses of standard and unknown must be selected carefully to be as uniform as possible with respect to weight, hereditary background, distribution of the sexes, and any other factors known to be important for the particular assay being carried out. The various groups of animals must be kept under as nearly identical as possible conditions of temperature, illumination, diet, and other environmental factors. Dilutions of the drugs for administration must be made in such a manner that all dosages of the drugs are given in the same fluid volume per unit of animal weight. The individual doses of the standard and the unknown drug should be assigned randomly to the subgroups of experimental animals and must be administered in as reproducible a manner as possible.

When death is not the end point of the bioassay, one can use a procedure of the "crossover" type. In this very advantageous kind of bioassay one set of animal subgroups is treated with the drug of unknown potency and a second set with the standard.

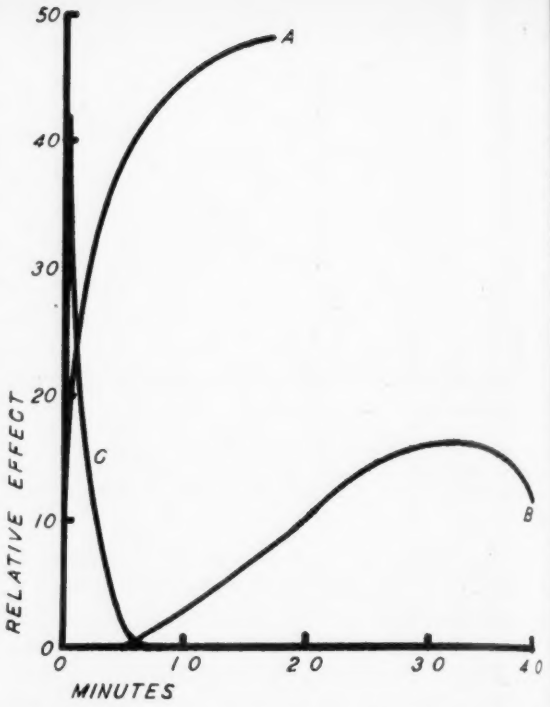


FIG. 4. Time-effect curves. The action on the isometric contraction of frog *rectus abdominis* of nicotine 1: 500,000 (*A*), of caffeine 1: 1250 (*B*), and of KCl 1: 500 (*C*). (Drawn from data of Clark.)

After an appropriate recovery period the two sets of animals are reversed, so that the one treated previously with the standard drug receives the unknown drug and vice versa.

Biological activity in homologous series. Variation in the structure of a molecule can affect the biological activity by altering the reactivity of the molecule or by changing the ability of the molecule to penetrate to the normal sites of reaction. Thus, the study of the systematic variation of biological activity within homologous series allows selection of the most potent representative of some particular family or allows identification within a family of those compounds having a desired action on certain organs to a greater extent than on others. Figure 5 shows three general sorts of curves obtained in studies of the systematic variations of biological properties in families of compounds with increasing numbers of carbon atoms in some side chain. Probably the most common effect in a homologous series is an increase in activity to a maximum as the chain length becomes greater, followed by a fall, caused frequently by the fact that increasing chain length decreases water solubility (curve *A*, Fig. 5). Sometimes the peak comes very early, so that there is only a decrease in activity as the series is ascended (curve *B*, Fig. 5). In other cases there may be a

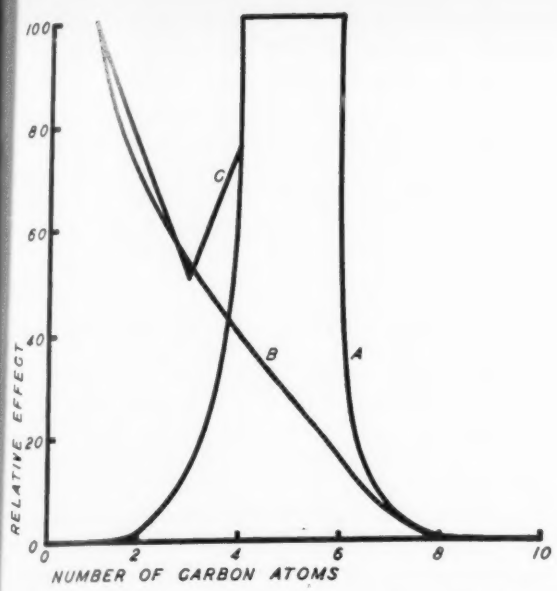
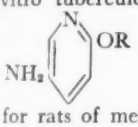
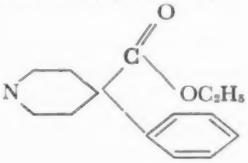


FIG. 5. Variation with length of carbon chain of biological properties of various families of compounds. *A*, the in vitro tuberculostatic action of members of the family  (from data of Burger); *B*, the toxicity for rats of members of the family RCNS (from data of von Oettingen *et al.*); *C*, the analgesic potency of members of the family  (from data of Schaumann).

second rise in activity, as shown in curve *C* of Figure 5. If this latter sort of curve were followed sufficiently far, there would probably be a second maximum of activity, followed by a decrease as water solubility became limiting.

In many series of homologous compounds, variation in the length of a carbon chain produces more complex alterations of biological activity than those shown in the curves of Figure 5. One fairly common sort of such complex variation is found in the series of monofluorinated fatty acids. Saunders has found that the omega-substituted fluorocarboxylic acids with even numbers of carbon atoms are much more toxic than the odd-numbered members. McCombie and Saunders concluded that CH_2FCO is the toxic group in all cases and that even-numbered members of the series are potent because this active group can be produced from them by β oxidation; conversely, β oxidation of the odd-numbered fluorinated fatty acids cannot yield this active moiety, and these compounds are not active. Similar alternations of activity have been found in the biguanide family of antimalarial drugs and in the 2,4 dialkyl phenoxyacetic acid series of plant hormones.

Compounds of a given series may have two or more major kinds of action, which do not necessarily vary in a parallel manner with alteration in structure. Thus, it has been found that removal of one phenolic hydroxyl of epinephrine decreases the pressor activity by a factor of roughly 4 but decreases the cardioaccelerator action by roughly 8 times. The same alteration of structure in the case of paredrine reduces pressor activity by about 1.5 times and reduces cardioaccelerator activity by about 55 times. Neosynephrine and benzedrine, the two products of hydroxyl removal, can be said, then, to have more specifically vascular actions than their parents.

Biochemical basis of drug action. Drugs altering the gross activities of cells must alter in some way the metabolic processes of those cells. It is an attractive hypothesis to say that they do so by selective toxicity for some enzyme involved in the intermediary metabolism of the affected cell. There is a certain amount of evidence in favor of this view. Many drugs have been found to alter enzymatic activity; in some cases such effects can be used to explain in whole or in part the biological activity of the compound tested.

The fact that a drug inhibits an enzyme does not mean, however, that inhibition of that particular enzyme is necessarily the mechanism of the biological activity of the drug. For example, the alkaloid veratrine, which produces a great prolongation of the contraction of muscle in response to a single stimulus, is a fairly potent inhibitor of the enzyme cholinesterase (Fig. 6). Inhibition of cholinesterase could explain the observed phenomenon by prolonging the existence of a local pool of acetylcholine set free by the initial stimulus. This possible mechanism has been shown apparently not to be operative, however, by experiments of Cicardo and of Miyake in which these workers found that veratrine does not change the threshold of muscle for acetylcholine.

Great caution must be exercised in concluding that enzyme inhibition as exhibited in vitro is the explanation for in vivo effects. One cardinal point to be considered in making such a transfer from an in vitro effect to an in vivo one is that the former must be accomplished by a concentration of the drug which could exist during the inception of the latter. One case in which this kind of transfer appears to be completely successful is that of the compound diisopropyl fluorophosphate (DFP).

FIG. 6. Effect of veratrine on cholinesterase activity of specific esterase from frog brain and of nonspecific esterase of dog blood. Effect on the specific esterase is about as great as that of morphine and about 1/230th that of physostigmine (from unpublished data of Wills).

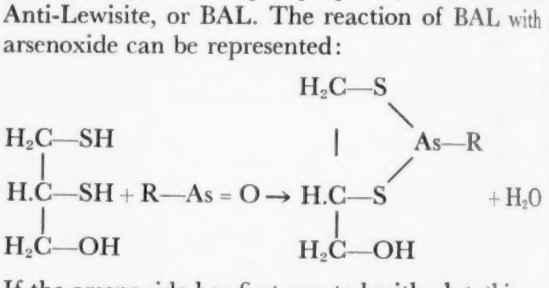
Mackworth, in 1942, studied the effect of DFP on cholinesterase and found that the compound has a potent inhibitory effect on this enzyme. This effect differs from those of previously known anticholinesterase agents, like physostigmine, in being irreversible. The pharmacological actions of DFP in animals and man have been studied by many different workers, and all appear to be explainable by postulating that the anticholinesterase action of the compound allows accumulation of acetyl choline, which then produces its usual effects: salivation, defecation, diarrhea, muscular twitching, difficult respiration, respiratory paralysis, bradycardia, arterial hypotension, heart block, ataxia, convulsions, and death. The development of these effects after administration of DFP is accompanied by lowering of the blood and tissue levels of cholinesterase. Moreover, many of the actions of DFP are blocked by atropine, which is known to block the corresponding actions of acetylcholine. We have, then, in the case of DFP, fairly good justification for believing that the mechanism of the in vivo actions of this compound is the inhibition of cholinesterase found in experiments in vitro. There are few other compounds having such a clear agreement between the in vivo and in vitro actions on enzymes.

In certain cases it should be possible to alter cellular activity without direct action on enzymes. For example, glutathione is an important cog in the oxidation-reduction systems of the body because it can serve as a reversible oxygen acceptor. Voegtlin and his associates have adduced impressive evidence that the toxic actions of the arsenical drugs involve reaction with glutathione, so that the oxidation-reduction cycle in the body cells is rendered incomplete by lack of this important component. In the case of the reaction between arsenoxide (R — As = O) and reduced glutathione (GSH), an equation like the following can be written:

$$2\ GSH + R{-}As = O \longrightarrow R{-}As(SG)_2 + H_2O.$$

The bound glutathione is unavailable for use in the normal oxidation-reduction reactions of the body.

The bound glutathione can be replaced by injection of free glutathione or by administration of some compound which has a greater chemical affinity for the As than glutathione. Such a compound is 2,3 dimercapto propanol, called British Anti-Lewisite, or BAL. The reaction of BAL with arsenoxide can be represented:



If the arsenoxide has first reacted with glutathione, two molecules of reduced glutathione will be set free by the action of BAL on the complex and will resume their normal function as oxygen acceptors.

Cellular activity can be altered by any drug action which changes the availability to the normal cellular biochemical mechanisms of any important constituent or metabolic intermediate. This can occur by direct reaction, as in the example just cited; there are at least two other mechanisms by which the same end result can be achieved. These will be denominated the "permeability" and the "statistical" methods. The name of the permeability mechanism is self-explanatory; a drug is supposed to alter in some way the properties of the cellular membrane so that important intracellular substances leak out of the cell or so that the supply of normal extracellular substrates to the cell is excluded. It is believed that the action of uranium on the nephron is an example of the first of these permeability mechanisms. Uranium appears, from the work of Dounce and Lan, to react with proteins in general without having an especially striking action on any enzyme. Uranium is thought to combine with the protein of the luminal margins of the cells lining the tubules of the kidneys. This reaction results in alteration of the permeability

of the cell membrane, so that such enzymes as catalase and phosphatase leak out before the occurrence of any change in cellular structure detectable by the ordinary staining methods. This loss of important enzymes, accompanied probably by loss of other necessary water-soluble compounds, leads later to death of the cell and to the appearance of readily detectable alterations in the cytology and histology of the kidney.

An example of the statistical mechanism for interference with metabolic processes is to be found in the Wood-Fildes theory of sulfanilamide action. This theory is based upon the finding that paraamino benzoic acid (PABA) inhibits the action of sulfanilamide on organisms in vitro and assumes that PABA is essential in bacterial metabolism. The theory then states that sulfanilamide and PABA (Fig. 7) are so similar in molecular contour that either one can occupy an "active surface" in the cell. Antagonism between the actively metabolized PABA and the unmetabolizable sulfanilamide depends, then, upon the relative affinities of these two compounds for the active surface and upon the relative numbers of the two molecules competing for that surface.

This statistical mechanism of drug action is an important one in modern pharmacology, being applied not only to antagonisms between drugs and essential metabolites but also to antagonisms between drugs. An example of the latter kind of statistical antagonism is shown in Figure 8. Here the durations of action of dibenamine in blocking the pressor effect of epinephrine with and without prior administration of 2-piperidinomethy-1,4-benzodioxane (933F) are compared. Because 933F is itself a blocking agent for the pressor action of epinephrine but with a less persistent effect than dibenamine, and because there are certain structural similarities between the two compounds, it is thought that this experiment demonstrates that both 933F and dibenamine react with the same active surface in the cell (this is postulated to be the same active surface with which epinephrine also reacts). Prior occupation of this surface by 933F prevents the access thereto of both dibenamine and epinephrine unless very large doses of the latter two drugs are used. The occupation of the surface by 933F lasts for long enough to allow complete removal of dibenamine from the circulating fluids of the body, so that the so-called epinephrine reversal after serial administration of 933F and dibenamine has the temporal characteristics of blockage by 933F rather than of that by dibenamine.

Radiation and radioactive isotopes. The work of the Manhattan Project early in World War II stimulated consideration of the toxicologic action of radiation. Construction of a successful chain-reacting pile, with the resulting large-scale production of many radioactive isotopes, provided both a potent tool for research use and a stimulus for the study of the fate within the body of many hitherto unstudied elements.

There are four main types of radiation that have to be considered today: α, β, γ, and neutrons. In general, the biological effectiveness of these radiations when tested in such a way that their penetrating powers are not limiting runs in the following order of increasing effectiveness: β, γ, neutron, α. In actuality, the α and β radiations have such low penetrating power that sources of these radiations are dangerous only on very close contact, as by settling on the body surface or by inhalation or ingestion. Sources of γ and neutron radiations, however, may be dangerous without actual contact with the body.

The α and β radiations, being charged particles, can be immediately dangerous by the local production of ions or free radicals. Neutrons and γ radiations have no intrinsic activity but produce charged particles in the tissues on which they impinge. These secondary products, in turn, produce ionization or free radical formation within the tissues. Tissues which have been damaged by radiation display the same qualitative histological changes whether the damage was induced by α, β, γ, or neutron radiation. The intensity of the injury may vary materially, however.

The exact mechanisms of the deleterious actions of ionizing radiations are not known. A prominent theory at the present time is that of activated water

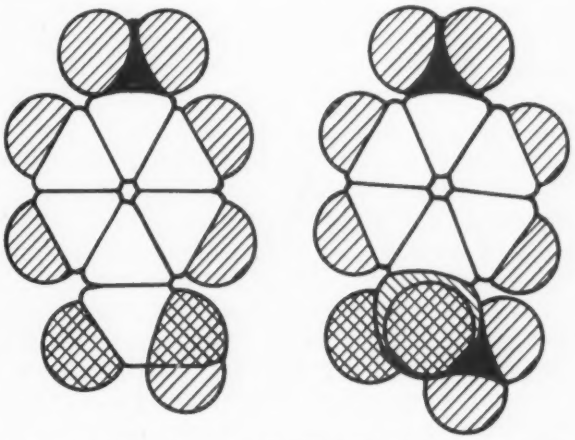


FIG. 7. Molecules of sulfanilamide (right) and paraamino benzoic acid (left), constructed with Fischer-Hirschfelder-Taylor atom models. White is carbon; single diagonal to left, hydrogen; single diagonal to right, sulfur; cross-hatch, oxygen; black, nitrogen.

reactions, according to which energy is transferred from the solvent to a solute. The primary process following the radiation of water may be represented thus: $H^+ + (OH)^- \longrightarrow H + OH$. The OH radical is a powerful oxidizing agent by virtue of the fact that by accepting an electron it is transformed to the $(OH)^-$ ion. It may be able to oxidize important groups, like the SH group, in enzymes: $2RSH + 2OH \longrightarrow R—S—S—R + 2H^+ + 2(OH)^-$. Such a reaction should be reversible by glutathione. To test this theory E. S. G. Barron has studied the inactivation by radiation and the reactivation by glutathione of 4 enzymes in which the SH group is important: phospho glyceraldehyde dehydrogenase, adenosinetriphosphatase, succinic dehydrogenase, and urease. In all cases it was possible to conclude that radiations act specifically and reversibly on sulfhydryl groups.

Attempts to establish precise lethal doses for radiations have not been successful because the lethal action varies widely with the site and manner of application of the radiation. For example, Ellinger found that in the rat the threshold for appearance of liver fat after whole-body radiation with X-rays is about 600 r; when the liver is irradiated directly, the threshold is about 2,500 r. Hagen found that in the dog the LD50 of X-radiation for a single exposure is about 250 r; Stebbins has found that when the dog is irradiated with 10 r per day, the cumulative LD50 is about 1,300 r.

Even though it is impossible to state a meaningful LD50 dose for radiation, it is possible to establish a level producing no damage which is not tolerable by the body. For constant daily exposure (8 hours per day) to radiation, this tolerable level has been set at 0.1 r per day of X-radiation. Bale has discussed recently the method for calculating the equivalent levels of radiations from other sources.

Radiations may have local or generalized action. The local actions include such effects as reddening, cracking, and blistering of the skin; production of cataracts in the eyes; rarefying osteitis with sequestrum formation, especially in the long bones; necrosis of the mucosa of the gastrointestinal tract; fibrosis of the lungs; cirrhosis; nephritis; atrophy of testes with oligospermia or azoospermia; and destruction of Graafian follicles in the ovaries. Certain tissues in the body are more sensitive to radiation than others; for example, the backs of the hands are comparatively resistant, and the germ cells and hematopoietic system are comparatively sensitive.

The generalized effects of radiation consist of nausea and diarrhea, abdominal cramps, headache, vomiting, low blood pressure, anemia, granulocytopenia, thrombocytopenia, and generalized hemorrhages. All these effects appear after a latent period of a few hours to several days. Two changes in the body fluids have been found which help to explain the mechanism of radiation sickness and which suggest therapy for its treatment. These are rises in the blood levels of histamine and heparin. Prosser, for example, has found that in the rabbit and dog the level of plasma histamine is 2-3 times the normal about 1.5 hours after irradiation of the whole animal with a lethal dose of X-radiation. The plasma level of histamine increases gradually until just prior to death, which occurs on about the tenth day after radiation. Allen, Milham, Sanderson, Kirschon, and Jacobson studied the clotting of blood from dogs irradiated with 450 r over the whole body at a single dose. They found that the clotting time was increased on the first day after the irradiation and continued to increase thereafter, so that in two dogs dying on the fifteenth day after radiation the clotting time was an average of 10.6 times that before the radiation. They were able to isolate from

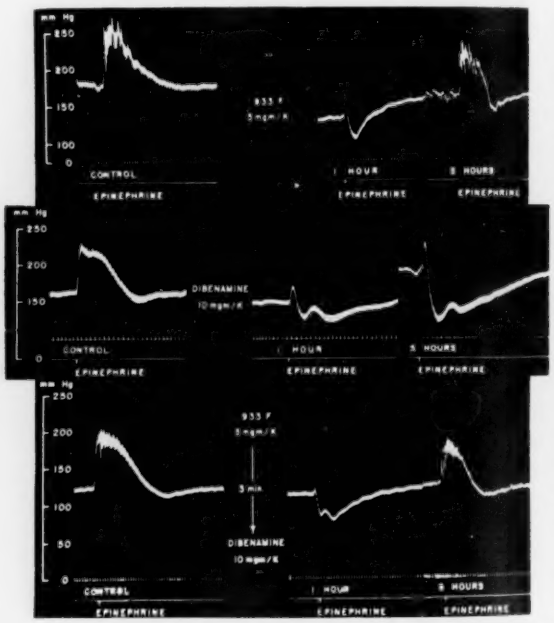


FIG. 8. Effect of a rapidly removable sympatholytic drug (933 F) in preventing combination with the epinephrine receptor of a slowly removable sympatholytic drug (dibenamine). Upper set of tracings: blocking of pressor effect of epinephrine by 933 F alone at 1 and 5 hours after injection of the blocking agent; middle set: blocking of pressor effect of epinephrine by dibenamine alone at 1 and 5 hours after injection of the blocking agent; lowest set: blocking of pressor effect of epinephrine by consecutive injections of 933 F and dibenamine at 1 and 5 hours after injection of the blocking agents. (Taken from work of Seed and McKay.)

the blood of irradiated dogs a substance capable of prolonging the clotting time of normal blood and having certain other properties of heparin.

These two findings suggest that radiation sickness could be treated with drugs combating the effects of histamine and heparin. Both antihistamine drugs, like pyribenzamine and neoantergan, and antiheparin drugs, like toluidine blue and protamine, have been found useful in the treatment of radiation sickness. Certain other drugs appear to have some value in the prophylaxis of radiation disease: Bean, Spies, and Vilter found that vitamins of the B group (especially pyridoxine, according to Maxfield, McIlwain, and Robertson) and Patt, Tyree, Straube, and Smith found that cysteine (but not cystine) given before radiation markedly diminish the intensity of radiation sickness, so that they act probably by interfering with the action of radiation on some important cellular component. In the case of cysteine this is probably SH-containing protein, like the enzymes studied by Barron.

A few other drugs have been found of value in the symptomatic treatment of radiation effects. Glenn and Reeves found that, of 65 patients with mild radiation sickness (nausea and diarrhea, with some abdominal cramps) after therapeutic X-radiation for cancer, 59 were benefited by trasentine or a trasentine-phenobarbital mixture. Because trasentine is a drug having the ability to relax spasms of smooth muscle, they concluded that the gastrointestinal upsets in radiation sickness are caused by some effect of the radiation on the musculature of the intestinal tract. They could equally well be caused by histamine, which has the ability to increase markedly the activity of the intestinal smooth muscle. Jenkinson and Brown reported that amphetamine sulfate or desoxyephedrine produced definite remission of radiation sickness in about 80 per cent of the 69 cases treated with one of these drugs. The effect is probably brought about by the physiological antagonism of these drugs to histamine. Mosely found that estrogens have some value in treating superficial areas of postradiation necrosis, probably because of their ability to produce dilatation of the small vessels of the skin.

In the fission process, occurring in an atomic bomb or pile, there are produced about 160 isotopes of something like 35 different elements. When the frequency of elemental occurrence among the fission products is plotted against atomic weight, it is found that the elements of atomic weights around 95 (Cb, Mo, Y, and Zr) and 139 (Ba, Ca, Xe) are the most common. The fate of a number of these elements in the body has been studied by the use of the easily identified radioactive isotopes. In such work it has been found by Hamilton and his associates that I and Cs are well absorbed from the gastrointestinal tract; that I, As, Ba, Cs, Ru, and Te are well to moderately well absorbed after intramuscular injection; and that the I, Cs, and Ru are excreted in the urine to a greater extent than in the feces. The other elements studied (As, Ba, Cb, Ce, La, Pr, Pu, Sr, Te, Zr, and Y) are excreted predominantly in the feces. Within the body Pr, Pu, Sr, and Y are deposited largely in bone, but I, As, Cs, and Xe are taken up to a greater extent by the soft tissues than by bone. The other elements are distributed more or less equally between bone and soft tissues.

These findings, in conjunction with a knowledge of the type and energy of the emission from each of these isotopes, allow one to assess the probable biological effects of the various radioactive species and to devise possible therapeutic measures against these effects. For example, the finding that both Pu and Zr are deposited in bone has suggested that the powerful α emitter, Pu, could be displaced from bone by nonradioactive Zr. Schubert has reported recently that injection of zirconium citrate into rats poisoned with plutonium increases the excretion of radioactive material by about 50 times that in the control plutonium-treated rats.

The use of radioactive isotopes as labels in pharmacological research has not been great but undoubtedly will grow as the usefulness of these materials for obtaining certain kinds of information becomes appreciated. There are two chief uses to which radioactive isotopes can be put in pharmacological research: study of the reactions between drugs and other constituents of the animal body, and following the localization and fate of drugs in the body. Examples of the first use are found in papers by Brauer and by Jandorf and McNamara. The first author studied the in vitro reaction of the anticholinesterase compound hexaethyl tetraphosphate (HETP), labeled with radioactive phosphorus, with human plasma cholinesterase and reported that no radioactive phosphorus could be found attached to the precipitated protein. He concluded, therefore, that a stable combination between the esterase and a phosphorus-containing fraction of HETP is not formed. Jandorf and McNamara have found that when DFP, labeled with radioactive phosphorus, is injected intravenously into rabbits, the level of the cholinesterase in the blood does not rise appreciably until elimination of radioactive phosphorus from the blood has begun. This latter finding has led to further analysis of the reactions of DFP and its relatives with proteins.

Jensen *et al.* found that, when chymotrypsin is inhibited in vitro with DFP containing radioactive phosphorus, there is incorporation of radioactive phosphorus into the protein molecule. They found that isopropyl groups from DFP are introduced also into the inactivated enzyme. Jandorf *et al.* have reported that radioactive phosphorus from tetraethyl pyrophosphate (TEPP), which also is a potent inhibitor of cholinesterase and chymotrypsin and which is responsible probably for the activity of HETP, is incorporated into the inactivated enzyme. Brauer and Pessotti, using HETP labeled with radioactive carbon in the α position, have found that radioactive carbon is introduced into cholinesterase during inactivation, extending to cholinesterase the finding of Jensen *et al.* that the alkyl group is incorporated into chymotrypsin. It appears, thus, that both the alkyl and phosphorus groups of the organic phosphorus cholinesterase-inhibitors react with the protein they inhibit. This reaction may involve loss by the enzyme of important components, such as active hydrogen atoms.

An example of an experiment in which radioactive isotopes are used for tracing the disposition within the body of molecules is found in an investigation by Simpson and Young of the absorption of BAL through the skin. The BAL was labeled with radioactive sulfur in the thiol groups and was then spread on the skin surface. The disappearance of radioactive sulfur from the skin was followed and was found to indicate a skin absorption of BAL of about 0.4 mg per square centimeter per hour. Another similar example is the use by Albright, Tabern, and Gordon of the amebacide chiniofon, made with radioactive sulfur, to study absorption and excretion of the drug. They found that chiniofon is absorbed rapidly from the gastrointestinal tract and that within 48 hours after administration of the drug about 60 per cent of the dose appears in the urine in an unaltered form.

The radioautograph method, whereby the radioactive isotope is made to mark its own location in a tissue, has been described by a number of authors (for example, Belanger and Leblond). This method is capable of yielding the most precise localization of isotopes emitting α particles but can be used with those yielding other types of radiation if absolute intracellular localization is not desired. For example, Axelrod and Hamilton studied the sites of fixation of radioactive sulfur in sulfur mustard and of radioactive arsenic in lewisite after application of these two compounds to the skin surface. It was possible to say that the greater part of each compound reacted with epidermal constituents. The two compounds differed by the fact that mustard penetrated into the corium to a greater extent than did lewisite.

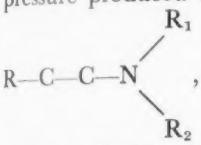
Autonomic drugs. According to neurohumoral ideas of the autonomic nervous system, acetylcholine is the transmitter of nerve impulses across ganglionic synapses in both the sympathetic and parasympathetic divisions and is the principle which excites the structures innervated by the parasympathetic division. It excites skeletal muscle also. Epinephrine, or adrenalin, or some closely related compound is considered to be the agent which excites the structures innervated by the sympathetic division. There is evidence that histaminergic nerves may exist in the autonomic system along with the cholinergic (parasympathetic) and adrenergic (sympathetic) ones.

The extent and duration of action of these neurohumoral transmitters are normally limited by such destructive mechanisms as the enzymes cholinesterase and histaminase. The effects of the neuroeffector substances can be increased or prolonged by drugs that either inhibit the activities of the destructive systems or compete with the neuroeffector substances for access to the destructive systems. Effector activity can be initiated also by compounds resembling the neuroeffector substance. The action of the effector compounds can be decreased or prevented by either increasing the activity of the destructive mechanisms or preventing access of these compounds to the trigger mechanisms of the effector cells.

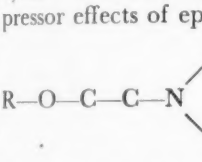
The three neurohumors of the autonomic system show an interesting relationship: acetylcholine can be written in the general form $RCH_2CH_2N^+(R_1)(R_1)(R_1)$; epinephrine in the general form $RCHOHCH_2N(H)(R_1)$; and histamine in the general form $RCH_2CH_2NH_2$. These generalized structures make it apparent that in all cases derivatives of ethyl amine are involved; they suggest further that there should be overlaps in the effects of these three types of compounds. In fact, there are interesting similarities and interrelations: both acetylcholine and histamine produce relaxation of the smooth muscle of the vascular system, as do also relatives of epinephrine in which the R_1 group contains 3 or more carbon atoms; acetylcholine and histamine both produce contraction of bron-

chial smooth muscle with resultant bronchoconstriction; acetylcholine potentiates the vasoconstrictor effects of epinephrine; epinephrine inhibits the hydrolysis of acetylcholine by cholinesterase; gastric juice secreted following injection of mecholyl always contains some histamine—in fact, more than similar juice secreted after injection of histamine itself.

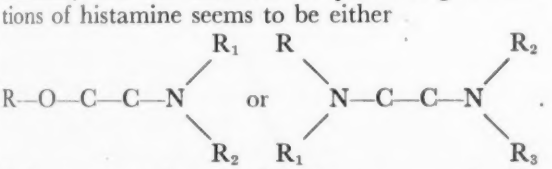
The compounds capable of blocking the action of the autonomic neurohumoral substances and their relatives are to some extent interrelated also: the minimal skeleton for blocking the fall in blood pressure produced by acetylcholine appears to be



, where R_1 and R_2 are alkyl groups and R is a rather large group containing a cyclic structure; the skeleton for blocking the pressor effects of epinephrine appears to be



, according to Seed and Calkins; and the skeleton for preventing the actions of histamine seems to be either



It is apparent that the blocking compounds, like the stimulating ones, can all be regarded as derivatives of ethyl amine and that here also a certain amount of overlap of effect should appear. Certain of the antihistaminic compounds, for example, possess also some antiacetylcholine effectiveness.

In most cases the relationship between the stimulating and the blocking compounds appears to be one of competition: the actions of small doses of the stimulating compounds are prevented by small doses of the blocking compounds, the block being overcome by larger doses of the stimulating agents. One notable exception to this generalization is the blockage of the pressor action of epinephrine by β haloalkylamines such as dibenamine. This block cannot be overcome even by massive doses of epinephrine, so that it appears that this particular type of compound produces an irreversible change in the receptor for epinephrine. During the period of about 1.5 hours required for this change to take place there is a proportional relationship between epinephrine and dibenamine (Nickerson and Gump), doses of epinephrine being effective but less so than usual.

Another interesting example of competition is found among the sympathomimetic amines. Jang has reported that in small doses these compounds potentiate one another's actions; when larger doses are used, however, the action appears to be antagonistic. These effects are believed to be explained by competitive occupation of destructive enzymes and of the receptive mechanism of the effector, respectively.

Another type of competitive action occurs in the group of anticholinesterase agents, including compounds like physostigmine and DFP. These substances appear to have little, if any, direct action on autonomic effectors; their effects all can be explained by the ability of these compounds to combine more strongly with cholinesterase than does acetylcholine and to allow thereby accumulation of acetylcholine which normally would be broken down by the enzyme. Topical application of physostigmine or DFP to the normally innervated eye produces constriction of the pupil by stimulating the circular muscle of the iris. Similar application of the same drugs to the chronically denervated iris, in which the local source of acetylcholine has been destroyed by degeneration of nervous structures, has no effect on pupil diameter. This result indicates that the anticholinesterase agents have no direct effect on the smooth muscle cells of the iris sphincter and exert, therefore, no action in the absence of a local source of acetylcholine.

In conclusion, it appears correct to say that in the century since the founding of the first laboratory devoted exclusively to the study of drug actions pharmacology has developed from a tradition-ridden state to something approaching a precise branch of science. There are many drugs the actions of which are not well understood or even described at the present time. The methods for drug study have been worked out fairly well, however, so that today complete description and understanding of drug action appear to be more a matter of sufficient repetition of known techniques than of development of new ones.

The Liberal Views of Lester F. Ward

BERNHARD J. STERN

The author (Ph.D., Columbia, 1927), who was assistant editor of the Encyclopaedia of the Social Sciences *from 1930 to 1934, has been a lecturer in the Department of Sociology at Columbia since 1931. He was lecturer in anthropology at the New School for Social Research 1932–43, visiting professor in sociology at Yale during 1944–45, and returned to the New School in 1949.*

GRANT ALLEN, the English publicist, once wrote aptly of Lester F. Ward, pioneer American sociologist, "Grasp is everything, and he grasps with an opposable thumb of no hesitation." It may truly be said of Ward that he exhibited none of the intellectual timidity that characterized many of his contemporaries. His work had an integrated purposefulness which gave it its stature. He was committed to the cause of intellectual freedom, and the diffusion of the results of that freedom, knowledge and social achievement, among the entire population. He did not hesitate to strike out at the forces which he conceived to be in the way of the "diffusion of knowledge among men." A friend in Washington, Frank Baker, editor of the *American Anthropologist,* wistfully replied to a rebuke by Ward in 1900, "I suppose I am a 'plastic' if by that you mean one who prefers to get along with people and things as we find them and make the best of a wicked world." Ward was intransigent in defense of his ideals, without being brash. He had convictions, and the unequivocating courage to defend them. In this moment of human history, this is perhaps the greatest lesson that a founder of sociology can transmit to his descendants.

The principles which he stoutly maintained should have met little opposition in terms of a functioning democracy. They arose out of his own experience in seeking to extricate himself from the poverty and ignorance that have ever been the lot of the common man. His youthful diary gives vivid documentation of the intensity of this struggle, and evidence that his experience was by no means unique. It is interesting in terms of the intellectual history of America, as yet unwritten, that his brother, C. Osborne Ward, who shared with him the failure in 1858 of the effort to make a living by manufacturing wagon hubs, chose a divergent road of intellectual and organizational expression. In 1869 Lester Ward, who was then employed as a government clerk in Washington, wrote the organizational call for the National Liberal Reform League, in which he appealed to

> . . . all who favor the objects above set forth, under whatever name they prefer to be styled—Liberals, Skeptics, Infidels, Secularists, Utilitarians, Socialists, Positivists, Spiritualists, Deists, Theists, Pantheists, Atheists, Freethinkers, all who desire the mental emancipation of mankind from the trammels of superstition, and the dominion of priestcraft, to unite in this movement and join the National Liberal Reform League without delay (*Glimpses of the Cosmos.* New York: Putnam's, 1913, I, 40).

About the same time (1870) his brother wrote *The Great Labor Party.* Lester Ward, influenced by Comte, had stressed social change through education. C. Osborne Ward, who had read and met Marx, advocated social change through the organized power of the working class.

Comte set the evolutionary pattern of Ward's thinking, but Ward added to it the peculiar muscular quality that was his. The nature of his opinions on social evolution is best expressed in a passage in *Applied Sociology* (1906):

> One after another the bulwarks of oppression—slavery, serfdom, feudalism, despotism, monarchy in its true sense, nobility and priestly rule—fell; the middle or business class, otherwise called *bourgeoisie* and third estate, gained the ascendant, which it still holds, and political freedom was attained.
>
> So all important did this issue seem that throughout the eighteenth century and down to near our own time it was confidently believed that, with the overthrow of political oppression and the attainment of political freedom, the world would enter upon the great millennium of universal prosperity, well-being, and happiness. But this was far from being the case. As sages predicted, events have proved that there remains another step to be taken. Another stage must be reached before any considerable degree of the hopes that were entertained can be realized. This stage is that of *social freedom.* The world is to-day in the throes of this third struggle. Military and royal oppression have been overthrown. Slavery, serfdom, feudalism, have disappeared. The power of the nobility and the priesthood has been broken. The civilized world is demo-

cratic, no matter by what name its governments are called. The people rule themselves by their sovereign votes. And yet never in the history of the world was there manifested greater unrest or greater dissatisfaction with the state of things. National freedom and political freedom have been achieved. Social freedom remains to be achieved (p. 27).

Ward believed that this "social freedom" was to be achieved by enlightenment through education, and thought that it was the function of sociology to propound this fact. He contended that "Society has never and nowhere been so organized to transmit the products of its achievement to more than a fraction of its members" (*ibid.*, p. 96), and that

> Applied sociology differs from other applied sciences in embracing all men instead of a few. Most of the philosophy which claims to be scientific, if it is not actually pessimistic in denying the power of man to ameliorate his condition, is at least oligocentric in concentrating all effort on a few of the supposed elite of mankind and ignoring or despising the great mass that have not proved their inherent superiority . . . whatever may be the differences in their faculties, all men have an equal right to the exercise and enjoyment of the faculties that they have (*ibid.*, p. 7).

This is clearly doctrine within the tradition of the Declaration of Independence. Yet, when Professor Edward L. Thorndike reviewed *Applied Sociology,* he attacked such views as "intellectual communism." They have since been repeatedly criticized as "equalitarian" and as ignoring individual differences. A careful reading of Ward would show at once the lack of validity of this criticism. When he argues that educational opportunity be given to submerged peoples Ward writes:

> This does not at all imply that all men are equal intellectually. It only insists that intellectual inequality is common to all classes, and is as great among the members of the completely emerged tenth as it is between that class and the completely submerged tenth. . . . Class distinctions in society are wholly artificial, depend entirely on environing conditions, and are in no sense due to differences in native capacity. Differences in native capacity exist and are as great as they have ever been pictured, but they exist in all classes alike (p. 100).

Thorndike's criticism of Ward went further than an application of an epithet. He declared: "This semi-acceptance of the common philanthropic view of public education as the preventer of crime and crutch for the weak, as the direct helper of the many through changes in them rather than their indirect helper through changes in the few whose increased achievements have demonstrably brought immense social returns, is the one feature of Professor Ward's book which may do real harm" (*The Bookman,* 1907, **24,** 291).

This controversy over the function of education is not of yesterday but of today and tomorrow. It is, in its most dramatic form, typified in the conflict between the fascist theory of the elite and the educational policy derived therefrom, and the democratic theory of education. It finds reflection in the eugenic controversy, in which Ward participated, and which has continued. Although the eugenists have been generally repudiated by the geneticists and have been practically routed from the scientific field, they still find expression in schools of education. The tempest over the constancy of the IQ, which tends to be low in groups of individuals deprived of educational opportunity, is blowing over with the tradition of Ward emerging triumphant, as evidence, in contrast with assertion, accumulates. Yet in this moment in history an asseveration in the educability of the common man and woman, and in the liberating influence of knowledge widely disseminated, is still a militant slogan, for democracy is still on the defensive against those who would abort its functioning.

The critics of Ward from the left do not in any sense depreciate the value of education. In fact, a reading of Ward's correspondence will reveal the fact that the bulk of his support during his lifetime came from socialist groups.

Their criticism of Ward arises from the fact that they have felt that such educational objectives were impossible to realize under the existing class structure of society. One will search in vain through Ward's complete works to find any statement as to how his educational program was to be instituted, or how his substitute for socialism, "sociocracy" (defined as "the scientific control of the social forces by the collective mind of society for its advantage"), was to be established. In fact, he at times gives clear and vigorous expression to the uses of education by class interests, which might well have caused him to modify his view that education alone would suffice:

> After the formation of caste, the inequalities among men were greatly increased and it was easy for a few of the higher class to keep the mass of mankind in subjection. This was accomplished primarily of course by force, but forms of deception were also constantly resorted to. The idea of the essential inferiority of the subject class must be steadily kept in the minds of that class. The least suspicion that this was not true would greatly disturb the social state. It was therefore a settled policy to enforce this idea, and a great variety of subterfuges were adopted to this end. At later stages, and even at the present time, those artificial social inequalities which enable the prosperous classes to thrive at the expense of the proletariat, and of the less favored classes where no true proletariat exists, are chiefly maintained through the systematic deception of the latter. . . . Deception may almost be called the foundation of business. . . . In politics the practice of deception does not differ as much as is generally supposed from that of business. While principle is

loudly proclaimed from the stump, interest lies behind it all. . . . Back of the politician and demagogue lie the "vested interests," and these it is that are "making public opinion." It is customary in these days to laud the newspaper, but, except for the little news that it contains, which is to its managers a secondary consideration, the newspaper is simply an organ of deception. Every prominent newspaper is the defender of some interest and everything it says is directly or indirectly (and most effective when indirect) in support of that interest (*Pure Sociology: A Treatise on the Origin and Spontaneous Development of Society*. [2nd ed.] New York: Macmillan, 1903, 486–7).

Yet Ward never advocated, as have Marxists, a change in the ownership of the instruments of production that they might function in the interests of all of society instead of in the interests of a few, and thus permit education to function likewise for the benefit of all the people. His program always remained nebulous, however progressive, as in the final pages of *Pure Sociology,* when he declared:

The question is being seriously considered why society as a whole, and all mankind from the highest to the lowest, should not profit by the brilliant achievements of the elite of mankind. Inventors and scientific discoverers are generous, and if they could dictate the policy of the world the results would be freely distributed and completely socialized. All they would ask would be a modest competency for themselves and their families and a decent legacy for their heirs. Alas! many of them never obtain even this. The results are taken up by the great economic world, as, indeed they should be and must be, if they are ever realized, and society only secures so much as cannot be prevented from filtering through the economic sieve which is often very fine. The great world movement of socialization is nothing else than the gradual recognition of this by society in its collective capacity, and the tardy, often fitful, inconsistent, and uneven, but yet sure and steady determination ultimately to claim and to have its full share in the achievement of the human race (pp. 571–2).

Likewise the last part of *Applied Sociology,* which was supposed to be the culminating formulation of his program, is, by all odds, the most ineffectual writing of his career.

Already in 1892, E. A. Ross had made strictures of his educational program. In a letter dated February 22, 1892, he wrote to Ward: "We want less injustice, oppression, parasitism and this is secured by more education. Should there not, then, along with developing intelligence to give us command over natural and social forces, go increasingly a developing sympathy to prevent the (socially) costly pursuit of individual gain? It seems to me this education to stir and stimulate the dormant sympathies of individuals is something different from the education you plead for" (B. J. Stern, Ed. The Ward-Ross Correspondence, 1891–1896. *Amer. Sociol. Rev.,* 1938, **3,** [3], 362.)

Alfred Russell Wallace, too, had written him in 1898, in a letter dated October 12:

What a terrible thing it is that under the present social system, the vast majority of the workers, however steady and well educated, have, and can have, no prospect but a life of toil and an old age of poverty or worse—and this when the work actually done, if properly organized, would provide not only necessaries but comforts for all, with ample leisure and a restful old age. Surely the coming century must see the end of the existing system of cut-throat competition, and wealth-production based on the misery and starvation of the millions! (B. J. Stern. Letters of Alfred Russell Wallace to Lester F. Ward. *Sci. Mon.,* 1935, **40,** 379).

Others, also, wrote in similar strain. But Ward to the end believed that not the private ownership of productive property but the inequality in the distribution of information and knowledge was the cause of the cleavage of society into an exploiting and an exploited class. Ward was on occasion emphatically critical of capitalism. In 1895, in an article entitled "Plutocracy and Paternalism" (*Forum,* 1895, **20,** 200–210), he wrote:

Nothing is more obvious today than the signal inability of capital and private enterprise to take care of themselves unaided by the state; and while they are incessantly denouncing "paternalism"—by which they mean the claim of the defenseless laborer and artisan to a share in this lavish state protection, they are all the while besieging legislatures for relief from their own incompetency, and "pleading the baby act" through a trained body of lawyers and lobbyists. The dispensing of national pap to this class should rather be called "maternalism" to which a square, open and dignified paternalism would be infinitely preferable.

In the following year he wrote of himself to Ross: "No one is more anxious to throttle the money power." In *Pure Sociology* he declared that "there has never been a time when the laborer received a just share of the wealth produced."

But he remained, as did the utopian socialists, purely a negative critic of capitalism, and a friend of labor who believed that "nearly all the real amelioration, and it is considerable, that has taken place in the condition of the lower classes has been due to . . . disinterested sympathy on the part of members of the upper classes who have more to lose than to gain by it" (*ibid.,* p. 93).

Nevertheless, Lester Ward gave hope to many through his stress of the potentialities of achievement of the common man. He once wrote: "The true crown of a system of scientific philosophy is not an Ethics which seeks to restrain and circumscribe activity, but a Sociology which aims at the liberation of action through the directive agency of intelligence." For this orientation rather than for any specific theory Ward is remembered today.

Glaciations in Little Cottonwood Canyon, Utah

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SLIGHTLY more than six decades ago, Grove Karl Gilbert, in his magnum opus, *Lake Bonneville,* indicated that evidence for the temporal correlation of Pleistocene glaciers in the Wasatch Mountains with high levels of lakes in the Great Basin would most probably be found at Little Cottonwood Canyon, an ice-carved defile southeast of Salt Lake City. Gilbert himself described a large mass of evidence there and from it drew a number of rational conclusions, subsequently shown to be correct.

Since 1890, additional study of evidence from Little Cottonwood Canyon by W. W. Atwood, Eliot Blackwelder, Ernst Antevs, and many others has approximately doubled the amount of factual material available, but has also produced a number of glacial and lake correlations, all containing substantial elements of correctness, but each lacking some fact essential for conclusive demonstration. These investigations, and those of Calkins and Butler, also produced voluminous evidence of a very early glaciation, which took place half a billion years ago, more or less.

* During the progress of this study, much valuable assistance in the field was given by a large number of local residents, most of whom are keen observers. The Salt Lake City offices of the U. S. Geological Survey, the U. S. Forest Service, and the U. S. Weather Bureau made their extensive files available to the writer, and offered many helpful suggestions. Discussions of field problems, and of the more difficult problem of correlations, with Drs. F. E. Matthes and S. R. Capps, of the U. S. Geological Survey, were found most helpful. The writer is indebted to the U. S. Soil Conservation Service for a large number of excellent aerial photographs, one of which comprises Figure 10 of this paper. Skilled pilotage, during aerial reconnaissances of the Wasatch and Uinta Ranges, was supplied by the late George Langham, Captain A. C. A part of the cost of preparing this report was covered by a grant from the Graduate Fund of Indiana University.

The center of the Little Cottonwood area is roughly 20 miles southeast of Salt Lake City, with which it is connected by several paved roads and an abandoned railroad right of way. The main canyon is traversed by a paved road as far as Alta, and by an improved gravel road to timber line; jeep trails extend to higher altitudes. Horse trails give access to all major tributary canyons and most of the important mines and prospects not on the main roads. Several mine tramways and a ski lift extend to points not otherwise easily accessible. Higher areas are snow-free only from mid-June to early September. Flying conditions, as in other parts of the Wasatch Mountains, are characterized by extremely rough air. General relation of the Little Cottonwood area to Salt Lake City, modern lakes, and Pleistocene Lake Bonneville is shown in Figure 1.

With a vertical range of 5,200–12,000 feet, Little Cottonwood Canyon has a variety of climates, covering the span from arid steppe land, locally made agriculturally productive by irrigation, on the flatlands near the canyon mouth to arctic tundra, much like that at Ivigtut, Greenland, in the summit area. Monthly temperature means and precipitation totals for base and summit are given in Figure 2.

Summit conditions at present are marginally glacial. Snow accumulations in some places carry over for as much as seven or eight years, then melt away during an abnormally hot summer. Only a few miles to the south, at Mount Timpanogos, a small glacier occupies a sheltered area of heavy snow accumulation. A rather slight lowering of mean temperatures, or a moderate increase in snowfall, would lead to permanent carry-over snow, or even to the formation of small glaciers in favorable locations.

Base conditions, away from the flood plain at the mouth of the canyon, are typical of the Jordan Valley. Not only is rainfall light here, and temperature high, but evaporation greatly exceeds precipitation. Strong local air circulations (anabats and katabats) modify the temperature ranges within the canyon and near its mouth, raising air temperatures on clear days and lowering them on clear nights.

It is notable that an over-all lowering of temperatures by about 10° F. would re-establish glacial conditions in the summit area, but even if mean base temperatures were 10 degrees lower, the canyon mouth would still be unfavorable to glacial growth.

For the stratigrapher and the structural geologist, this area has an almost nightmare complexity, but the geomorphologist finds the essential features of the area relatively simple. All the area west of the Wasatch Fault system (*Fault,* Fig. 1), which trends roughly north and south along the mountain front, is surfaced by Tertiary and later sediments, none of them highly resistant to glacial and other erosion. In consequence, terrain carved from these beds has a steplike profile.

East of the Wasatch Fault, which is the western boundary of the Wasatch Mountains, bedrock consists of an extensive sequence of quartzites, limestones, sandstones, and shales, of various ages from Pre-Cambrian to Jurassic, and containing, at the base of the Cambrian, rather extensive tillites (to be detailed later). Into these sediments have been intruded various monzonites, diorites, and granodiorites, at some later date, perhaps in late Cretaceous time. Because of the similarity of these intrusives, particularly the monzonite, to those in the glaciated portions of the Colorado Front Range, comparisons of depth of weathering since glaciation may be made with some hope of correctness, particularly in view of the climatic similarity of the two areas.

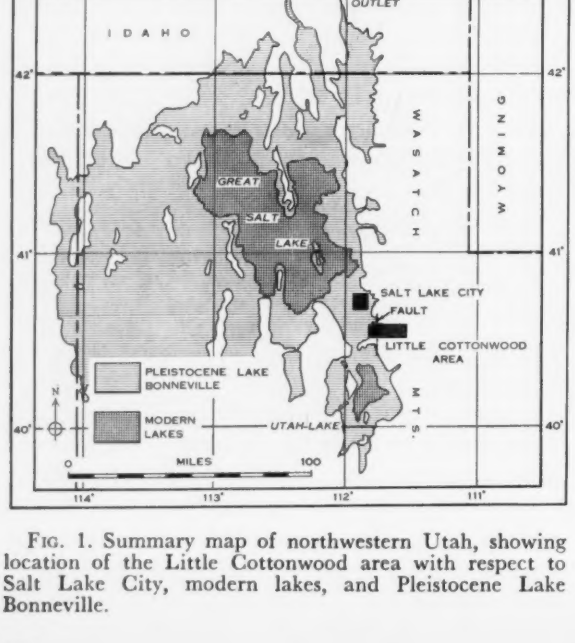

FIG. 1. Summary map of northwestern Utah, showing location of the Little Cottonwood area with respect to Salt Lake City, modern lakes, and Pleistocene Lake Bonneville.

Complicating the entire stratigraphic picture, but having little apparent effect on Pleistocene glacial features, are several fault sequences and a large number of minor intrusions, of various types and ages. These, and the interesting mineralogy of the area, have been described in great detail by Calkins and Butler.

Early Cambrian (?) Glaciation

Near the base of the stratigraphic section, in Little Cottonwood Canyon, and elsewhere in and near the Wasatch Mountains, is a thick laminated shale, containing boulders of various sizes and angularities. General structure of this material is substantially identical with that of the clay in the famous Don Valley Brickyard, near Toronto, Canada, or in the ancient bed of the Passaic Lake, not far from Wayne, New Jersey.

Nature of evidence. The tillites of the Little Cottonwood area consist of a matrix of laminated shale, dark-gray on freshly broken surfaces, weathering to dark-red or reddish-purple. In a few areas, exposed surfaces of this tillite are nearly black. Contained within this matrix are numerous angular, subangular, and rounded boulders, of various sizes from 30 inches long down to pebble dimensions. Many of the boulders are asymmetrical, most have at least one flattened and polished surface, a few show definite striae. These may be seen most clearly when a wet rock surface is viewed through a Polaroid screen.

Most of the contained boulders are composed of quartzite, quite similar to the subjacent Pre-Cambrian quartzite. A few granite boulders are present, and resemble no known local granite. Several loose or partially dissolved pebbles of nonfossiliferous limestone, of unknown age and origin, have been noted, but these are not common. General appearance of this tillite is shown in Figure 3.

Greatest known extent of this tillite is in the area between Big Cottonwood and Little Cottonwood canyons, where thickness is somewhat in excess of 1,000 feet, and several exposures are more than a mile long and 1,500 feet wide (Fig. 4). Considerable evidence has been buried by later deposits, or masked by reworking.

Tillite exposures in the Little Cottonwood area are in broad bands, trending north and south.

Many exposures have been incised by Pleistocene glaciers; many others have probably been buried by recent glacial deposition. Many tillites are shown on older geologic maps as "conglomerate," a classification which is quite correct, but decidedly misleading.

This tillite is by no means confined to the Little Cottonwood area, but extends interruptedly at least 5 miles southward, 8 miles eastward, 25 westward, and more than 100 miles northward. (See inset, Fig. 8). Reasonable extrapolation suggests that considerable areas of tillite are, or may be, concealed by Pleistocene deposits or modern lake waters in the Bonneville basin.

The tillite thins rapidly southward, so that none has been identified south of American Fork Canyon, immediately south of the Little Cottonwood area. Northward the thinning is more gradual, exposures of tillite being scattered over a wide area extending at least as far north as the Utah-Idaho state line.

Age of tillite. Dating of this tillite is still rather indefinite. The deposits are nonfossiliferous, and are separated from adjacent beds by unconformities. The tillite is not older than later Pre-Cambrian, for it rests unconformably upon the upper Proterozoic quartzites of the region. Likewise, the tillite is not younger than Cambrian, for it is overlaid unconformably by the Tintic quartzite, of Cambrian age. Because the interval after the deposition of the Pre-Cambrian quartzite and before that of the tillite was considerably longer than the interval between the deposition of the tillite and that of the Tintic quartzite, Calkins and Butler date the tillite as Cambrian (?).

There is no assurance that all the tillites near the western edge of the Wasatch Mountains are of *exactly* the same age. Those west of Ogden have a more granular matrix than those near Little Cottonwood Canyon, and the included boulders at the northern location are more angular. Whether these changes in texture indicate a tillite of different age and origin, or are merely a slightly different phase in the same deposition, remains undetermined. Textural changes of about the same magnitude are not unknown in the moraines of a single Pleistocene glacier.

Significance of evidence. Volume of the ancient tillites exposed on the western fringe of the Great Basin is about two and one-half times that of the Pleistocene deposits in the same general area. If a reasonable and conservative correction is made for probable attrition of these ancient deposits, it may be assumed that their original volume was at least five times that of the Pleistocene moraines.

This tillite appears beyond any reasonable doubt

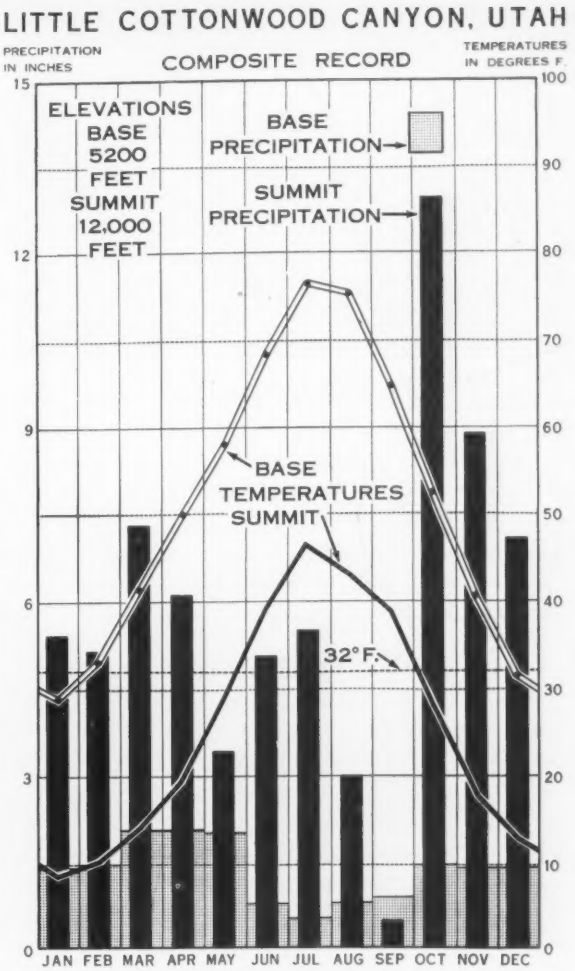

FIG. 2. Comparison chart, showing base and summit temperatures and precipitation in the Little Cottonwood area. Base chart is considerably more accurate than summit chart.

to be a glacial deposit, laid down where a very large glacier discharged into a body of quiet water. Shaping of included boulders, fineness of matrix grains, thinness of matrix laminae, and thickness of the entire deposit all indicate involvement of a considerable time interval. Extrapolation from a number of laminar counts indicates that this interval was at least $N \times 10^4$ years, but suggestions of interrupted deposition, and absence of laminae in some parts of the deposit, preclude any satisfactory estimation of an upper age limit.

Reconstructed shape of the deposit, with maximum thickness toward the south, coupled with a decrease in the angularity of the components southward, indicates a glacier with a northern source, probably not nearer the area than the Utah-Idaho state line, and a southern terminus having a possible mean position just north of Little Cotton-

FIG. 3. Fragments of very early Cambrian tillite, showing boulders and matrix, at base of talus of same material. (Photograph by B. S. Butler, from USGS.)

wood Canyon. Laminar nature of the matrix, from north of Ogden to the supposed position of the terminus, indicates deposition in a quiet water-filled valley, perhaps in a fiord, a type of deposition which may account for the absence of a striated and polished basement beneath the tillite.

Pleistocene Glaciation

Pleistocene glaciation in the Wasatch Mountains was first noted by various members of the U. S. Geological and Geographical Survey of the Territories about 1872, and numerous references to it are to be found in their voluminous reports. A clear, concise description of the glacial deposits at the mouth of Little Cottonwood Canyon, and of their apparent relation to the ancient lake beds in the Bonneville basin, was published by G. K. Gilbert in 1890. A thorough study of the entire area by W. W. Atwood, in 1909, produced a satisfactory map, showing what was, and what was not, glaciated in this area. Discrepancies between glaciated areas, as shown by Atwood, and those noted in the field were in large part not only inconsequential, but were quite obviously due to shortcomings in the base map used. Remapping of parts of the area by U. S. Geological Survey parties, completion of an aerial mosaic of most of the Wasatch Range, and integration of a large number of surveys by the U. S. Forest Service have eliminated a part of the base map difficulty, but the area still suffers from multiple nomenclature, "phantom" fractions, and indefinite locations of many features of little economic importance.

To reduce misunderstandings, a base map of Little Cottonwood Canyon and adjoining areas, using the U. S. Forest Service nomenclature of 1942, is here included as Figure 5.

Canyon mouth moraines. Visible from a distance of several miles, and obvious even to a nongeologist, is the sequence of moraines flanking Little Cottonwood Creek on each side just west of the canyon mouth. Notable also, about midway in the length of each moraine sequence, is a fairly deep graben, still steep-walled, and only slightly modified by the rather rapid erosion and deposition of this semi-arid locality. The southern group of moraines, which intimately adjoin those of Bell Canyon, immediately to the south, are best preserved (Fig. 6). As will be made obvious by illustrations, a considerable part of the morainal deposit at the mouth of Little Cottonwood Canyon has been concealed by faulting and burial; an unknown part is absent because of either erosion or nondeposition. Moraines at the mouth of Bell Canyon are better preserved, but the loops have been interrupted by a graben (Fig. 7), as have the lateral moraines on both sides of Little Cottonwood Canyon.

Field study of this morainal complex discloses moraines of four different ages; the most recent two, however, are separated by a very short time interval, so that, were they as old as the oldest materials found, they would be classed as of only one age. Arrangement of these various morainal deposits about the canyon mouth is shown in Figure 8. The asymmetrical arrangement of the moraines at the mouth of Little Cottonwood Canyon is notable.

The oldest, and outermost, glacial deposit here, to which, for use in this study, the local name "Graniteville Erratics" has been applied, is found fairly high on the north slope at the mouth of Little Cottonwood Canyon (Fig. 6), and in eroded areas west of the Wasatch Fault opposite the mouth of Bell Canyon. Where exposed, these erratics consist of Little Cottonwood quartz monzonite; where buried, decayed granodiorite, of upper-canyon origin, is also present. Components of this material are so decayed that they can be drilled with a thumbnail, and disintegrate into a slimy gravel on short exposure to the air. Material tentatively identified as Graniteville Erratics, and disintegrated to the same degree, has been uncovered in a number of excavations west of the Wasatch Fault, and is mixed with clay (lake beds) which contains decalcified and decayed gastropod shells. These old lake beds are tentatively correlated with the Bonneville yellow clay, which antedates the Bonneville shore line, oldest recognized in the basin.

Arrangement of the Graniteville Erratics with respect to Bell and Little Cottonwood canyons suggests that they comprise the remnants of a terminal loop, perhaps of the joint Little Cottonwood and Bell Canyon glaciers. There is no evidence indicating or even suggesting that Little Willow Creek (Fig. 5) was glaciated at this time.

Next younger morainal sequence is found closely

adjacent to the Graniteville Erratics, and is, in general, within the reconstructed terminal loop. This sequence, which is best developed at the mouth of Bell Canyon, is here called the Bell Canyon Old Moraine Series, and is substantially coextensive with the Older Moraines mapped by Atwood. Only two small exposures of this material are found on the north side of Little Cottonwood Canyon, where it is present as a low, erratic-studded bench, directly below the Graniteville Erratics (Fig. 8). Surface exposures of this material consist in large part of Little Cottonwood quartz monzonite, with a few small fragments of granodiorite. Buried members of the Bell Canyon Old Moraine Series contain large decayed boulders of granodiorite and similar rocks, which can be split with a shovel when first exposed, but which harden on drying, so that after a few months of exposure to the air the central core can be worked only with a rock drill.

Between Little Cottonwood and Bell canyons, this moraine sequence appears to have been shared by glaciers in both canyons, and hence is present as a medial moraine. A rather large and well-developed terminal loop is present west of Bell Canyon (Fig. 8). Sectors of both lateral portions of the Bell Canyon terminal loop are missing, because of faulting and subsequent burial of the down-faulted morainal segments under slope wash.

In several locations near the point where Bell Creek cuts the outer edge of this moraine sequence, stratified deposits rest upon the outer edges of the moraines. These beds are sandy marls, containing unfossilized and beautifully preserved *Lymnaea bonnevillensis* and other gastropod shells. This material is similar to the Bonneville white marl in its type locality, Gilbert's "Old River bed," and certainly is of nearly the same age, as is indicated by the condition of the contained shells.

Volume of the Bell Canyon Old Moraine Series is about thirty times that of the Graniteville Erratics, so that, even when a generous allowance is made for attrition of evidence, it appears that the Bell Canyon Old Moraine Series represents a glacial stadium of very much greater duration than does the Graniteville Erratic deposit.

The name Cottonwood *A* Moraines has been applied, for use in this study, to the next younger glacial sequence in this area. This group of moraines is best developed on the south side of Little Cottonwood Canyon, where it has a length of about a mile. Moraines of this same age line the upstream side of the Bell Canyon Old Moraine

FIG. 4. Tillite bed on north wall of Little Cottonwood Canyon, at about longitude 111° 39′. Tillite bed is designated by *T*; pre-Cambrian quartzite by *Q*; and Mississippian limestone by *LS*. Tillite and limestone are separated by the Superior Fault Zone, which is visible near center. Note Pleistocene glacial forms and recent talus in Peruvian Gulch (foreground). (Photograph by F. C. Calkins, from USGS.)

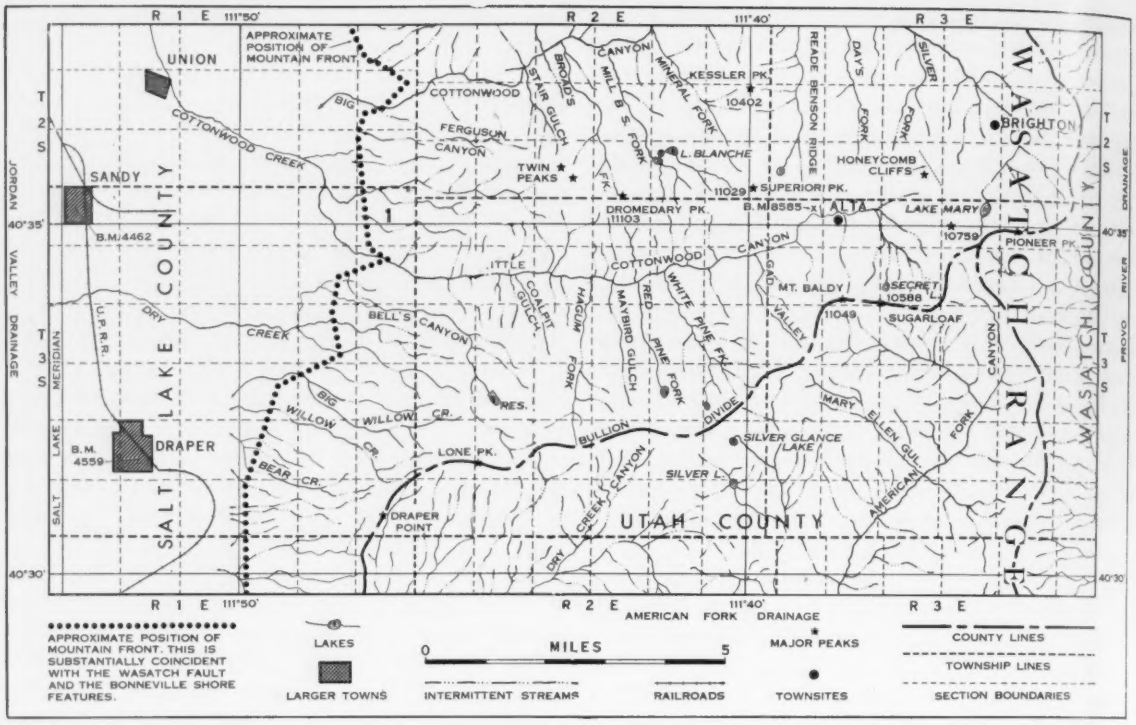

FIG. 5. Summary map of Little Cottonwood Canyon and adjoining areas, showing drainage, principal points of interest, and pertinent terrain divisions.

Series in Bell Canyon, forming a compound morainal loop, and choke the mouth of Little Willow Canyon, just north of Little Cottonwood Canyon.

On the north side of Little Cottonwood Canyon, the Little Cottonwood *A* Moraines are present as low ridges, just below the older moraines. It appears that the ice of the Little Cottonwood *A* Glacier, during this advance, overrode its terminal loop to the northwest, so that the original morainal topography was suppressed in that direction, and that erosion of this morainal gap, at a later date, removed much of the remaining glacial deposit (Figs. 6, 7, and 9).

Moraines of the Little Cottonwood *A* series contain slightly weathered, but substantially undecayed, boulders from all parts of the upper canyon. Although morainal gradients are steep, and local drainage is good, these moraines have not been deeply gullied, despite the torrential rains that are common along the west face of the Wasatch Range. Volume of material in these moraines is about double that in the Bell Canyon Old Moraine Sequence, but, as a part of this volume may be due to superposition upon, or assimilation of, older morainal deposits, it appears probable that this glaciation was of about the same magnitude as that which produced the Bell Canyon Old Moraine Series.

Within and without the moraines of the Little Cottonwood *A* series, at and near the mouth of Little Cottonwood Canyon only, are extensive relatively flat deltaic deposits (*Flats*, Fig. 5), with an upper surface about 5,250 feet above m.s.l. This is slightly above the level of the Bonneville shore line at its nearest exposure. These delta beds are axially discontinuous, along Little Cottonwood Creek, and the gap is partly filled with fine stratified micaceous sand, which is classed as a lake bed, rather than as a delta deposit.

Upvalley from the Little Cottonwood *A* moraines, within them, and just within the canyon mouth, is another moraine, of comparatively small volume, composed largely of relatively fine materials. This is here called the Little Cottonwood *B* moraine. Although this moraine is a distinct topographic entity, deposited within the loops of the Little Cottonwood *A* series, and hence is of lesser age, amount of erosion and weathering of the *B* series is substantially the same as that of the *A* series, indicating that the *B* series is not much younger than the *A*.

Similar moraines are present in Bell Canyon, in the same relative location (Fig. 8), and having the same relative magnitude. No moraine definitely identifiable as Little Cottonwood *B* was found in Little Willow Canyon, but erosion there could well

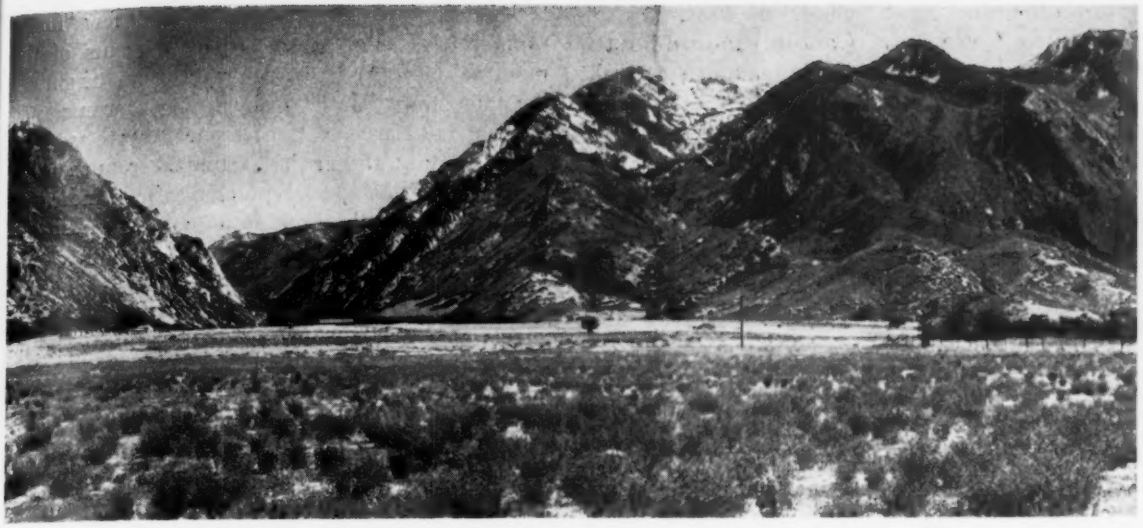

FIG. 6. View eastward from the western edge of the flat at the mouth of Little Cottonwood Canyon, showing relations of flat to canyon, and to the moraines of the Little Cottonwood and Bell Canyon glaciers.

have removed it, or altered it beyond recognition by ordinary field criteria.

Mid-canyon moraines. For several miles above the Little Cottonwood *B* moraine, which is just within the canyon mouth, Little Cottonwood Canyon is substantially clear of morainal material, except for a very thin layer of reworked material in the stream bed, and has a "double-decked," or "two-story," U profile, indicating quite clearly that it was glaciated at least twice. Weathering differences in the upper and lower decks indicate that the time interval between cycles of glacial erosion was considerably greater than that since the last series of ice advances. Alignment of moraine crests with breaks in the valley wall gradient, after due allowance for fault displacement, indicates that the younger, and lower, U profile is related to the younger glaciations, which include the Bell Canyon Old Moraine Series, and the Little Cottonwood *A* and *B* moraines. Correlation of the older (and upper) glacial U profile with the Graniteville Erratics, and possibly with other glacial advances of the same general age, of which no remaining evidence has been found, seems entirely plausible, but is not demonstrated conclusively by the evidence now remaining.

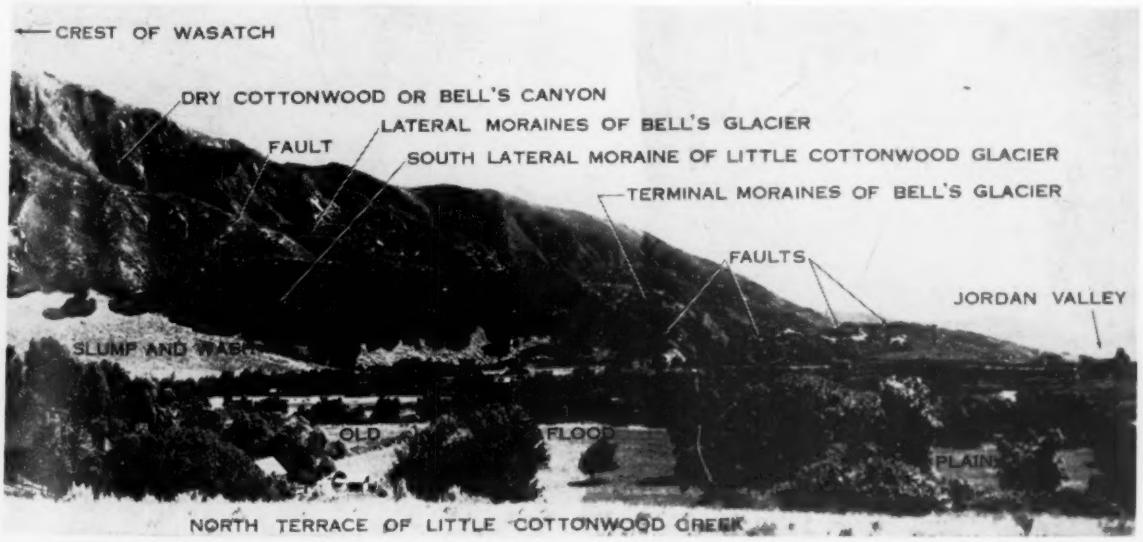

FIG. 7. Photodiagram of the south wall moraines at the mouth of Little Cottonwood Canyon, as seen from the north terrace. Foreground moraines are the south laterals of the Little Cottonwood glacier; moraines in background, and partly concealed, are those of the Bell Canyon glacier.

From the junction of Yellow Pine Fork (Fig. 5) with Little Cottonwood Canyon, upward to the drainage divides above Alta, the main canyon walls and floor are lined with morainal material, mixed with a relatively large amount of talus and slide rock, but only two important glacial stadia are evidenced by large morainal loops. Lowermost of these, at Yellow Pine Fork, is composed of large, angular, substantially unweathered fragments of quartzite, granite, and limestone, with few "fines." Quantitative analysis of the components of this moraine indicates that most of them originated not more than 2 miles from it, an occurrence suggesting that many of the fragments were loosened by landsliding, rather than removed from their initial locations by glacial plucking. This indication is supported by the notable absence of polish and striae on the erratics.

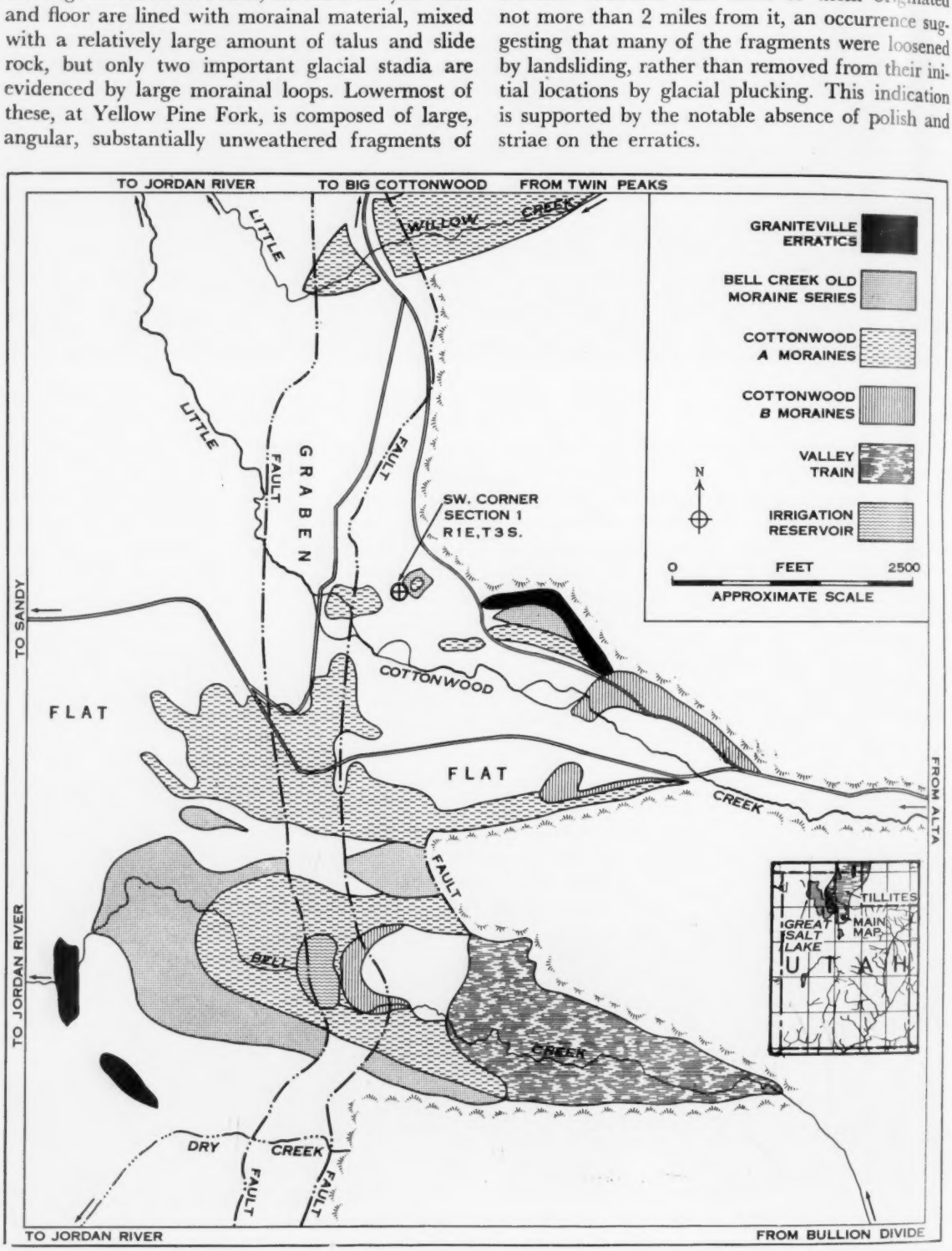

FIG. 8. Summary map of the moraines adjacent to the mouth of Little Cottonwood Canyon. Inset shows areas in north central Utah from which Cambrian or older tillites have been reported.

Slightly less than two miles farther upstream, at the mouth of Gad Valley Gulch (Fig. 5), is another morainal loop, composed also of angular, substantially unweathered fragments of medium to large size. These, like those at Yellow Pine Fork, are not striated or polished, but composition of the rocks present shows some from each part of the former glacial basin.

Similar morainal loops, of very small dimensions, are present in some of the major tributary valleys, but are difficult to identify with any certainty because of interruption and concealment caused by erosion, solifluction, and burial under talus. In Bell Canyon (Fig. 8), these later moraines, mixed with talus, alluvial deposits of a torrential type, and avalanche dumps, are mapped as valley train.

From the Gad Valley moraine to just west of the Alta townsite, the valley floor is covered with morainal deposits of no great thickness. These culminate in an apparent morainal loop at the west side of Alta, which rests on alluvium, apparently occupying a filled lake basin. Cursory examination indicates that this is a moraine-dammed lake, but careful inspection of the outflow channel discloses that the "morainal loop" forming the dam is actually a barrier of bedrock, very thinly veneered with morainal deposits. In consequence, the former Alta Lake occupied a rock basin, and not a moraine-dammed valley.

These mid-canyon moraines are all of approximately the same age, as is indicated by degree of dissection, depth of weathering, and erosional removal of fines. This same evidence indicates that the mid-canyon moraines are very much younger than the canyon mouth deposits, but also that they are not historically recent. When due allowance is made for differences in past and present climatic conditions between the canyon mouth and the mid-canyon area, the statement that the mid-canyon moraines are about half as old as the Little Cottonwood *B* moraine seems within reason.

Canyon-head moraines. In a majority of the cirques which eventually drain into Little Cottonwood Canyon, as well as those tributary to Bell Canyon, multiple morainal loops are present. These, usually of small volume, extend not more than 1.5 miles downvalley from the cirque headwall. Spaces between loops are filled with wash, peat, and slumped material.

Rocks comprising these moraines are angular, not polished, and not striated. Much fine granular material is still present in depressions among the moraines: some of the small lakes are floored with rock flour, covered only by a fraction of an inch of organic material. This is in marked contrast to conditions in lakes at lower elevations, where thick layers of peat are present. Superficially, components of the upper moraines appear no more weathered than similar rocks on adjacent mine dumps. Fractured sections, however, disclose that discoloration in similar rocks extends about four times as deep in morainal components as in mine dump materials.

Except in areas of great concentration of runoff, such as the floors of the larger cirques, there has been no dissection of these youngest moraines. Small streams flow over and among morainal components in many places, and have not eroded them appreciably.

These moraines are considerably less than half as old as those at Yellow Pine Fork and Gad Valley, but they are also very much older than the oldest mine dumps in the area, some of which are at least seventy years old. Age of most of the moraines in the major cirques is about the same as that of the outer moraines at Timpanogos Glacier, approximately 15 miles southeast of the Little Cottonwood area.

Although these moraines, which for convenience will be referred to as the Albion basin moraines, are now present as a discrete, small sequence, their long-term geologic importance is slight, for any major glaciation would immediately remove them and would probably also destroy all trace of the Gad Valley and Yellow Pine Gulch moraines.

Postglacial Features

The time that has passed since the ice melted away behind the Albion basin moraines is short, geologically speaking, and may be short even in terms of written human history. Since the disappearance of this ice from most cirques, two geologic mechanisms have been at work—solifluction and avalanches. Both have produced notable changes in upland topography. In most of the higher cirques, talus has accumulated upon, around, or in place of, glacial ice in such quantities that it has buried a number of moraines of the Albion basin sequence and has become mechanically unstable, so that the accumulations have become rock glaciers (Fig. 10). Similar features are present in Alaska, the Colorado Front Range, and the Sierra Nevada of California. Many of the rock glaciers in the Little Cottonwood area are still in slow erratic motion, rapid enough to damage trees in a few locations (as in upper Yellow Pine Fork).

Avalanches are numerous each winter in Little Cottonwood Canyon and its major tributaries and constitute an appreciable transportation hazard. Definitely identifiable avalanche deposits, consist-

FIG. 9. Suppressed morainal topography on north side of Little Cottonwood Canyon. Morainal materials of Little Cottonwood *A* stage are here superposed on a flattened deposit of materials of the Bell Canyon Old Moraine Sequence. Location is near the southwest corner of Sect. 1, T3S, R1E (Fig. 5).

ing of piles of angular rock fragments, at the lower ends of cleared strips in the forested slopes, and often containing undecayed timber, are numerous in Little Cottonwood Canyon. Other deposits, which are probably avalanche "dumps," but in which timber is lacking, are found in many places. Avalanche scars in timber can be seen from the air throughout the Little Cottonwood watershed and in adjoining areas.

Datings and Correlations

Desirable, in a study of this type, is a correlation of the local glacial phenomena with those in other studied areas, and also with all other contemporary phenomena in the area considered. Present evidence, however, does not permit exact correlations of these phenomena to "three significant figures." Approximate correlation of glacial stages in Little Cottonwood Canyon with those in the Monarch Valley, Colorado, and adjacent areas, is possible; and some relation between glacial stages and lake stages in the vicinity of Little Cottonwood Canyon is shown by the evidence.

Colorado–Utah correlations. Similarity of terrain, rocks, and climates in Little Cottonwood Canyon and the Monarch Valley makes possible rather close correlation of depths of weathering and degree of dissection of morainal deposits. In the Little Cottonwood area, the morainal deposits have the same number, approximate magnitude, areal distribution, and degree of dissection as those in the Monarch Valley. Because the Albion monzonite of the Colorado Front Range is substantially identical to the Little Cottonwood monzonite, checking of age estimates by comparison of depth of weathering in areas of similar climate is possible. On the basis of these criteria, it appears that a close correlation of glacial deposits in the two areas can be made (Table 1).

When the Monarch Valley study was made, the Stillwater Stage, which is separated from the later morainal deposits by a very long erosional interval, was classed as Iowan. Since that time (1936), the Iowan has been redated, so that it is now considered as the oldest Wisconsin substage, rather than as a separate glacial stage. In consequence, the Stillwater Stage is now regarded as of probably Illinoian age. Likewise, its Utah correlative, the Graniteville Erratics, are tentatively classed as Illinoian; but the possibility of an intermediate glacial stage, between Illinoian and Wisconsin, still merits some consideration.

TABLE 1

Correlation of Glacial Deposits in Little Cottonwood Canyon, Utah, and the Monarch Valley, Colorado

LITTLE COTTONWOOD CANYON	MONARCH VALLEY
Albion Basin	Neva Basin
Gad Valley Yellow Pine Fork	Monarch C B A
Little Cottonwood B Little Cottonwood A	Arapaho B Arapaho A
Bell Canyon Old Moraine Series	River Stage
LONG TIME INTERVAL	
Graniteville Erratics	Stillwater Stage
LONG TIME INTERVAL	
No earlier Pleistocene glacial evidence	Older Pleistocene moraines

Notable, in the Little Cottonwood area, is the absence of any evidence of pre-Illinoian glaciation, whereas in the Colorado Front Range area such evidence is plentiful. In contrast, there is no evidence even suggesting early Paleozoic glaciation in the Colorado Front Range in the near vicinity of the Monarch Valley (*ca.* Lat. 40° N.); but remaining glacial deposits of late Pre-Cambrian or very early Cambrian age in the Little Cottonwood area have a greater volume than those of Pleistocene age.

Relation of glacial deposits to lake beds. From the time of Gilbert's field work (1885) to the present, it has been the opinion of most geologists that the relation of alpine glaciations in Utah to the various stages of Lake Bonneville will eventually be determined from evidence near the mouth of Little Cottonwood Canyon, where the glaciers extended out into the bed of Lake Bonneville. Studies by Gilbert, Blackwelder, Antevs, and others have all produced evidence and some possible answers to the problem, which is complicated by the existence of at least three separate lake chronologies, all based on about the same evidence.

Review of the published evidence, augmented by field checking and by an excavated section across the mouth of Little Cottonwood Canyon (trench for new aqueduct), discloses that practically all the evidence cited by earlier workers is either correct, or within reason; that the conclusions from this evidence, even though they cannot all be correct, are at least a rational extrapolation from the facts; and that exact correlation of all the glacial evidence now known with all the lacustrine evidence in the area of proximity is not yet possible.

Despite the incompleteness and possible ambiguity of the evidence, however, many relations are indicated with some clarity. The Graniteville Erratics are approximately contemporaneous with the Bonneville yellow clay, a deposit antedating the cutting of the Bonneville shore line. This would place the pre-Bonneville lake stage in pre-Wisconsin, and probably in Illinoian, time, a conclusion in substantial accord with most earlier datings, which are based on practically identical evidence.

Outer moraines of the Bell Canyon Old Moraine Series, which are tentatively correlated with the River Glacial stage of Colorado, and dated as early Wisconsin, are overlaid by lake beds quite similar to the Bonneville white marl, a bed correlated with the incision of the Bonneville shore line. If this evidence is correctly interpreted, the first rise of lake waters to the Bonneville shore line took place after, but probably not very long after, the maximum extension of the Bell Canyon glacier.

At a considerably later date, probably in mid-Wisconsin time, another glacial maximum occurred, and produced the Little Cottonwood *A* moraines, which show indications of a fairly complicated glacial history. During the later stages of this ice advance, the morainal loops were filled with, and surrounded by, deltaic deposits to about the 5,200-foot level. Evenness of the upper surface of this delta (*Flat,* Fig. 8) is attributed by Blackwelder to prograding against a lake level not far below 5,200 feet. Such an occurrence would call for a second rise of lake waters to the Bonneville level, as has been indicated by evidence at and near Cup Butte. Multiplicity of glacial stadia during Little Cottonwood *A* time is apparently paralleled by multiple lake stadia during the same time.

Later lake stages are not related to later glacial stages by direct evidence, but two major lake stages, the Stansbury and the Dugway, correspond approximately in temporal spacing and magnitude to the two later glaciations, the Yellow Pine Fork–Gad Valley and the Albion basin.

The above relations are more suggestive than conclusive, so that use of multiple working hypotheses is still desirable in any study of the Pleistocene chronology of this area. Notable here is the absence of any conclusive evidence of both early Pleistocene glaciation and early Pleistocene lakes. It is entirely possible that the Bonneville basin did not become an area of interior drainage until well into Pleistocene time.

Field evidence from Little Cottonwood Canyon and its immediate vicinity shows plainly that the

FIG. 10. Rock glaciers in cirques on the south side of Little Cottonwood Canyon, north of Bullion Divide, near the head of Yellow Pine Fork. In many locations, moraines in cirques have been buried by these rock glaciers.

area was extensively glaciated in very late Pre-Cambrian or very early Cambrian time; that it was not glaciated in early Pleistocene time; and that the area was occupied by glacial ice, of local origin, at least five times during the latter part of the Pleistocene, probably from Illinoian through Wisconsin, with a majority of the continental ice advances represented.

Correlations from Little Cottonwood Canyon to the Monarch Valley are quite obvious and can be made with considerable confidence, there being no important differences between the morainal deposits, or the conditions of formation and preservation, in the two locations.

Correlation of the glacial stages in Little Cottonwood Canyon with the stages of Lake Bonneville cannot be made with any great confidence as yet, despite the close proximity of the evidence, for even where the evidence itself is clear, its implications are subject to multiple interpretations. At the time of this writing (spring, 1950), it appears that the oldest moraines—the Graniteville Erratics—are substantially contemporaneous with the Bonneville yellow clay, a deposit antedating the incision of the Bonneville shore line: that the Graniteville Erratics and their time equivalents are probably of Illinoian age: and that all later major lake and glacial deposits date from the Wisconsin.

The youngest and uppermost glacial materials—the Albion basin moraines—are identical in appearance to both the Neva glacial materials of Colorado and the "Little Ice Age" deposits of California and hence may be dated, with some hope of correctness, as not much more than four thousand years old. This is very nearly the same age as that assigned to the minor Dugway Lake Stage, on the beaches of which old Indian camps, containing modern-type artifacts (as contrasted to Folsom), have been found.

The Little Cottonwood area is also notable for its easily accessibility. Whereas most areas of geologic interest are "two days beyond the end of the trail," the Little Cottonwood area is only an hour's drive from Salt Lake City, over paved roads, and most of the "critical" evidence is either visible from the road or is within a few hundred feet of it. This happy geographic arrangement makes it possible for an interested person to make a firsthand inspection of the major features of the area at little cost in time, energy, or money.

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Science in General Education

EARL JAMES McGRATH

The author (Ph.D., Chicago, 1936) left his post as professor of education at the University of Chicago in March 1949 to become U. S. Commissioner of Education. During the war years, he was an educational and personnel adviser with the Navy, the National Roster of Scientific Personnel, and the War Manpower Commission. He is a former editor of The Journal of General Education. *Dr. McGrath will head a mission to Israel this summer to survey that country's educational problems and advise its leaders. His article is based on an address given before Section Q at the New York Meeting of the AAAS in 1949.*

SINCE development of the atomic bomb in 1945, our citizens have shown an unprecedented awareness of the part science plays in shaping public affairs. Beginning with the publication of the Smyth report, *Atomic Energy for Military Purposes,* more and more books about things labeled "science" and persons called "scientists" have found their way onto the best-seller lists. Examine the titles most in demand at local libraries. Among them are such works as *Explaining the Atom, Modern Science and Its Philosophy,* and *The Universe and Doctor Einstein.* The reading public is curious, inquisitive—eager to learn about this great but overwhelming force of the mid-twentieth century.

A closer examination of popular contemporary titles, however, reveals a significant phenomenon. Side by side with books about science are such works as these: *Peace of Mind, Peace of Soul, Guide for Confident Living, You and Your Fears,* and *How to Stop Worrying and Start Living.* Our citizens are disturbed and confused. The complexities of living in the Atomic Age make for mental insecurity. Today we find ourselves groping desperately for serenity, searching for answers to questions which seem beyond our grasp.

Apparently, we are seeking not only to understand the forces that determine events in our world, but also to relieve the tensions indirectly created by those forces. It is of crucial importance that we find that understanding. For until we do, tensions continue to mount. And as developments we do not comprehend move out of our control, we may succumb to a sense of utter futility. In this direction lie chaos and the collapse of democratic institutions.

The responsibility for breaking into this frightening circle rests, in great part, upon the shoulders of the teacher of science. For here, potentially, is a key figure in every community in the land—an individual who should be at once a scientist, an educator, and a citizen. Let us direct our attention to this threefold role.

The essence of science is its method. Fundamental to the approach of a scientist is the idea that reality is to be regarded as a process: the concept that no two things are exactly alike; no one thing stays the same. Such a point of view fosters a readiness to change as changing conditions require. With adaptability as one of its characteristics, the scientific method entails asking clear questions, seeking and reporting unprejudiced observations, and, of course, revising unsubstantiated assumptions in the light of the confirmed findings of research.

As one who has mastered this method of inquiry, the scientist might well ask himself whether or not he is applying it "across the board." Can he transfer the ability to ask clear questions and make unbiased observations to his everyday life outside the classroom and the laboratory? Does he stand ready to revise certain assumptions he may hold in the realm, say, of economics when new evidence is presented? Does he realize the limitations of science and scientific methods in determining what is the good life? Is he as adaptable in his social views as he is in the face of evidence that makes a previously accepted chemical hypothesis untenable?

In short, how many of us are part-time scientists? Are we fulfilling our obligation to our profession and to society by failing to put into general practice the method we espouse in our specialized fields? Perhaps it is time scientists took stock of themselves as *scientists.*

The scientist as *educator* stands in need of introspection, too. For all the recent progress in general education, there are still a very great number of institutions—on both the secondary and college levels—with curriculums organized in watertight

compartments. One bloc of courses will bear the label "physical science," another "biological science," a third "social science," and so on. Very little, if any, attempt is made to integrate them and to establish for the student the important relationships existing among the various disciplines. Efforts to bridge or penetrate the barriers between departments are sometimes jealously resisted.

If the student somehow grasps a relationship between biology and psychology under such conditions, it is likely to be coincidental, not planned. If a high-school physics teacher suggests that he might possibly have something to offer students in world history, he may be viewed as an interloper. An observer from Mars, looking down on a typical American high school or college, could get the impression that here, indeed, are several different worlds under one roof.

The sufferer in all this is the student-citizen and therefore society. As things now stand, he has a good chance of learning certain biological and physical "facts of life" about the world in which he lives. But his chances of understanding the impact those sciences have on our society, and what he as an individual can do to control and/or modify the effects of that impact, are all too often practically nil.

It is difficult to single out a field of modern scientific endeavor that does not touch in some way upon the public interest. Atomic energy is only the most-publicized enterprise. Current research in biochemistry, for example, may bring about radical changes in methods of treating certain diseases. This, in turn, is sure to affect our system of training qualified medical personnel. The answers to questions scientists are asking today will influence each of us in some way tomorrow. The student-citizen has a vested interest in the relationship between science and its effects. It is precisely here that the teacher of science becomes a general educator.

In so far as general education in science is concerned, the emphasis should, I believe, center around teaching the nature of the scientific method. Unless our student-citizens know something about the essence of science and the basic features of its method, they, as voters, will not be able to make intelligent decisions on many questions. Despite the recent interest shown in books about science and scientists, how many of our citizens can understand what it is that a scientist is trying to do? Can the average citizen mark off, with any degree of accuracy, the distinction between a scientist and a nonscientist? More pertinent to our discussion here, perhaps, would be the question: Could our high-school and college science students make that distinction?

The success of courses stressing science as method could be measured by the extent to which the student transfers his learning to situations outside the science classroom; that is, he must learn to relate the basic features of the scientific method to everyday living. To illustrate, let us take as an example one characteristic of scientific inquiry, that of reporting unprejudiced observations. "Prejudice" literally means to "prejudge." Scientists do not prejudge, and the science student should learn at an early stage of his schooling that prejudging is the very antithesis of the scientific method. He would be taking a tremendous step forward as a citizen if he could learn to discipline himself against prejudgments in social, economic, and political matters.

But the student cannot be expected to relate science and its method to the world about him unless the teacher of science is himself a student of relationships. To be an effective educator, the science teacher must, it seems to me, demonstrate by his own example the great value of studying relationships among the various disciplines. It can be put even stronger than that: we must prepare educators in all fields—science included—who are committed and prepared to teach relationships. In this connection, would it be prudent to wonder out loud how many teachers of physics have read the Atomic Energy Act of 1946? Physics teachers —all science teachers, for that matter—who have read and studied that far-reaching piece of legislation can count themselves as being persons who are searching for an understanding of relationships.

I should like to inject here a few words about science courses in our high schools. Less than 20 per cent of students go on with their formal education after high school, so the integration of science with other fields of study is primarily a secondary school function. Science instruction in the high school—if it is to be a vital part of a general education program—would deal with real problems and real things and would seek to develop an understanding of the principles and theories related to them. Conventional science courses are designed largely as preparatory instruction for further science courses. If these can be so broadened that the student can relate the subject matter to his physical world, the science teacher will have struck a powerful blow for citizenship education. The theories and principles, I hasten to add, should grow in significance as the individual matures, and should continuously enrich and make meaningful the life of the individual whatever his lot may be.

Similarly, I think general courses in science should be organized at the college level. Close cooperation on a state or regional basis between the high-school and the college teachers of science can help eliminate excessive duplication. In planning such courses, care must be taken to avoid compartmentalization of subject matter. There is some question as to just how much benefit a student can derive from a course which offers him three weeks of this, three weeks of that, and three weeks of something else without any attempt to relate the fields explored. The type of general course I am advocating would cut across boundaries—assist the student, in fact, to interrelate the various disciplines.

This approach to science education may necessitate drastic revision in teaching methods. For example, a great deal can be said for utilizing the seminar or discussion method as a teaching technique, as against the conventional lecture-recitation device. For, in a good discussion, the student does something more than just memorize formulas; he develops an ability to synthesize ideas and think critically.

In addition to the general instruction, there must, of course, be specialized work for those who are going into scientific careers. My own opinion is that we should not attempt to provide special training for these people until they get beyond the high-school level. I see no reason, therefore, for the highly specialized emphasis in the high schools. Those who demonstrate ability in science during or when they leave high school can be identified by various tests. A strong guidance program can be utilized to place them in specialized courses where this is desirable. The premedical student, for example, could be placed in an elementary zoology course.

Even those persons who expect to major in the sciences in college should, I believe, be given more instruction dealing with the scientific method and the impact of science on modern life. At a recent faculty meeting in one of our leading land-grant colleges, a botanist—one of the foremost specialists in the country—was arguing against developing a program of general education for that institution. He turned to a colleague in the Department of Government who favored the new program and said: "Why can't we keep things the way they are now—you teach the kids what they ought to know about government, and I'll teach them what they ought to know about botany!"

Our botanist friend missed, tragically, the lesson we all should have learned by now from Hitlerite Germany and Stalinist Russia—overspecialization in education means that, on social and political problems, the few decide for the many. In a democracy, the critical decisions must never become the province of "specialists." But in order to decide with wisdom, all the people in a democracy must be equipped to evaluate facts and relate them to basic principles.

This brings us to the role of the scientist-educator as a *citizen* in a democratic society. Do far too many teachers of science seem to view their function in strictly ivory-tower terms? Does their private little world begin and end in the classroom or laboratory? Do they teach and act as though science operated with no relationship to everyday living in home and community? Do they pay no attention to the world outside and, by example, press their students into doing likewise? If so, would not our observer from Mars, watching these apostles of specialization, reflect that they have a singularly poor notion of the social situation in which science operates and which it helps shape?

I believe, frankly, that it is high time that scientist-educators join the community and take an active part in civic as well as in school affairs. They can begin by facing up to the overriding question: Science for what? They can do this by participating in school forums and community adult education programs, and by offering their services to the local newspapers and radio stations as interpretive writers and speakers. Theirs is the job of making science and its methods understandable to the lay citizen. Theirs is the job of revealing how science touches the problems of human existence and the hopes that people cherish for improved living.

For from now on, the citizen will be called upon constantly to make decisions which may mean life or death for the scientific enterprise. An ignorant citizenry could—and may—easily wreck that enterprise or stunt its growth unless scientists turn their attention outward from their laboratories to their communities. The scientist-educator must evince more and more that awareness of the great problems of our time long since manifested by such leaders as Harold Urey and J. Robert Oppenheimer. The scientific spirit cannot flourish without democracy, and scientists, acting as citizens, must join the front ranks in democracy's fight for survival.

SCIENCE ON THE MARCH

THE MECHANISM OF LUBRICATING OIL BREAKDOWN AND ITS RELATION TO OIL CORROSION*

REACTIONS in an internal-combustion engine are varied, complex, and uncertain. Lubricating oil temperatures range from 250° F. in the oil sump on a warm day to 300° F. in the bearings and 400°–500° F. at the ring belt. Oil is whipped around as a mist in the crankcase and in this manner adsorbs considerable quantities of air. This adsorbed air serves to increase the rate of oil breakdown by at least three times when the oil is subjected to heat and pressure in the bearings and at the ring belt. Under such unfavorable conditions it is no less than astounding that an internal-combustion engine can operate any length of time without major repairs.

Lubricating oils are hydrocarbons and therefore, under such conditions as those enumerated above, are subject to oxidation. The breakdown process is necessarily very complex. The order of events and the intermediate reaction products depend on such factors as the structure of the original oil molecules, the temperature, pressure, presence of air, carbon monoxide, carbon dioxide, metallic catalysts, and others. Such a combination of factors introduces a considerable element of uncertainty into any speculation about the nature of intermediate products.

The step-by-step oxidation might be illustrated, however, by the progressive breakdown of a simple hydrocarbon such as methane:

$$\text{Methane} \rightarrow \text{Methyl Alcohol} \rightarrow \text{Aldehyde} \rightarrow \text{Formic Acid} \rightarrow \text{Carbonic Acid}$$
$$CH_4 \longrightarrow CH_3OH \longrightarrow HCHO \longrightarrow HCHO_2 \longrightarrow H_2CO_3$$

Each addition of oxygen is a partial combustion reaction and is, therefore, exothermic. The heat generated in each stage is absorbed in part, at least, by the molecule undergoing degeneration. The result is a rise in temperature of the molecule and an acceleration of further reactions. This may mean partial cracking if the reaction is going on in larger molecules, and the formation of methane, ethane, and other light hydrocarbons, which are held in solution to a more or less limited extent in the lubricating oil. The step-by-step combustion would then proceed about as indicated above for methane.

The lower aldehydes formed from monobasic alcohols are strong reducing agents and therefore oxidize readily to the lower fatty acids, such as formic acid B.P.213F, acetic acid B.P.227F, propionic acid B.P.286F, and butyric acid B.P.326F, all of which are vapors under engine conditions.

The H of the acid radical is readily replaced by metals such as aluminum, copper, iron, lead, and zinc, to form the metal formates, acetates, etc. Therefore, these acids are highly corrosive, their activity being an inverse function of the number of hydrogens that can be replaced. Furthermore, these acids are much more active at the moment of formation. They are formed and liberated principally in the maximum pressure areas of the bearings and ring belt, where the oil temperatures are also maximum. In these regions their activity is apparent in the form of pitting of bearings and in cylinder wall wear. Ventilation of the crankcase to remove these volatile acids is of no material advantage, for damage is done when the acids form, which is long before they can be freed from the oil.

The reactions involved in corrosion could then very well be, without bothering about coefficients:

$$Cu + O \rightarrow Cu\ O \qquad (1)$$
$$HCHO + Cu\ O \rightarrow HCHO_2 + Cu \qquad (2)$$
$$HCHO_2 + Cu \rightarrow Cu\ (CHO_2)_2 \qquad (3)$$

Equation (1) represents the slight oxide film which forms on metal surfaces. Equation (2) is the reaction between the aldehyde, a strong reducing agent, and the oxide film, to yield formic acid and a particle of free metal which at the moment is in an active state. The formic acid immediately unites with the metal particle as in equation (3) to give the metallic formate. The formate either passes into solution or colloidal suspension in the oil. The actual nature and state of the final product do not matter. What does matter is that a particle of metal from the engine has passed into the oil.

A new lubricating oil is composed of much larger molecules than indicated by methane. The higher aldehydes and acids, which are less harmful, form first. As progressive degeneration of the oil occurs, however, the lower acids make their appearance. The extent of oil breakdown, therefore, can be determined by measuring the temperature at which volatile acids form. This is readily accomplished by passing the vapors from the oil through a sensitive indicator as the oil is slowly heated and noting the

* Acknowledgment is made to the University of Nebraska Research Council for financial assistance to conduct a portion of these researches.

temperature of the oil at which the indicator changes. The temperature at which acid vapors are first liberated is known as the "acid vapor temperature" of the oil.

The acid vapor temperature of new lubricating oils ranges from 250° F. to 330° F., depending on the oil and the additives in the oil. As the oil is oxidized either by laboratory methods or on the road, the acid vapor temperature gradually drops to a low of under 100° F. The oil in this latter condition has long since passed its useful life.

Correlation of acid vapor temperatures with incipient corrosion has been the subject of investigation in the author's laboratory for several years. These studies have followed four methods of attack: gravimetric, microscopic etch, discoloration of copper strips at temperatures which ranged from 122° F. to 300° F., and microanalysis for metals in the oxidized oil.

The gravimetric method has finally been discarded because too many uncertain factors enter, one of which is the time element involved to produce measurable results. Prolonged exposure of a metal during oxidation of the oil does not take into account progressive breakdown of the oil, and therefore no relation can be established between incipient corrosion and acid vapor temperature. The method is only reasonably useful to determine total weight loss of the metal in a given time.

Microscopic etch studies of metal strips placed in the oil as it is oxidized are open to about the same objections. From these studies, however, an approximate acid vapor temperature of 200° F. for incipient corrosion was somewhat vaguely established.

The method of discoloration of copper strips placed in the oil is open to error because of gum, carbon, and sometimes sulfide deposits on the copper. Best results are obtained when the test is made at 300° F. under oxidizing conditions. This is a simple and rapid test, and requires only thirty minutes. It is valuable if the results are properly interpreted. The test actually is only a measure of the oxide or sulfide films which form on the copper surface. It is just one step in the corrosion process and therefore does not present the complete picture.

The use of organic reagents for microanalysis of metals in the oil that has been oxidized under controlled conditions presents other difficulties, which have been largely overcome. The metallic complexes that may be soluble or in colloidal suspension in oil must be broken down and removed from the oil by suitable methods, which depend somewhat on the organic reagents to be used for their detection. By these methods the incipience of corrosion has been related to an acid vapor temperature, which has been established at 215° F. for copper. Curiously, this is the approximate vaporization temperature of formic acid. A further check of the vapors liberated from an oil whose acid vapor temperature is 215° F. shows these vapors to contain formic acid.

Samples of oils taken from cars and trucks show that the end of the useful life of the oil is reached at 600–1,500 miles. This depends somewhat on the driving conditions and on the type of oil used. In general, the appearance of the oil has no definite bearing on the extent of oil breakdown. A perfectly clear oil may have reached the danger point as far as its acid vapor temperature is concerned. Filters that keep the oil relatively clear and that are advertised as extending the useful life of the oil do not remove the compounds from which the corrosive vapors are derived.

Finally, it must be emphasized that the acid vapor temperature need not indicate the presence of free acids in the oil. It is, however, the measure of the temperature at which volatile acids form, and when this temperature drops to a rather definite point it is an indication of incipient corrosion. A lubricating oil must be considered as having reached the end of its useful life when its acid vapor temperature drops to 215° F.

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HIGH-CALCIUM LIMESTONE USES

LIMESTONE is truly a basic mineral raw material. The availability and adaptability that promoted the extensive use of limestone and its derivatives promise also an ever-increasing variety and volume of uses in an expanding economy.

Stone that yields lime when burned has been dignified with the name "limestone" by many generations, but modern usage tends to recognize as limestone that rock which contains more than 50 per cent of the natural salt calcium carbonate. This seems simple; yet systematic, detailed classification of the carbonate rocks is an exceedingly complex

problem that has resulted in a vast array of qualifications and exceptions. Within the group of rocks which properly may be called limestone, every possible variation of calcium carbonate content occurs in nature. Physical variations, too, in far greater number than the chemical, add to the difficulty of description.

The systematic classification of limestones is approached by different interested groups, who each establish bases of grouping most meaningful to themselves. Geologists usually consider the origins of limestone as fundamental in setting up "types" of limestone; other important considerations are more tangible—such as texture, structure, degree of cementation, and the consistent presence of identifiable impurities. Users and suppliers of limestone are interested in how limestone qualifies for various uses. Limestones used for building, ballast, road aggregates, and similar purposes are rated by tests that are primarily physical. Agricultural limestones are evaluated usually by a chemical-like analysis that establishes their neutralizing value. Purchasers of flux, chemical, or other special-purpose limestones are most interested in the chemical analyses of the stone. These analyses may be abbreviated to indicate only the amounts of calcium carbonate and two or three major impurities, or they may be quite complete. In any case, representative chemical analyses are becoming increasingly important to the adequate description of any limestone deposit. A number of systems of classification based upon chemical composition have been suggested, but none has been adopted to the exclusion of others. "High-calcium limestone" is a term that seems to have been introduced by a specification-minded group of users and producers; the term generally is understood to refer to limestone that contains 95 per cent or more calcium carbonate.

Reliable chemical analyses clearly establish which limestones are of high-calcium quality, yet each user obviously will further investigate any limestone he considers. He may establish the fact that he can afford to use a relatively impure stone because of other economies (usually of location), if his needs are flexible. Since each problem is individual, the appellation "high-calcium limestone" may appear to be of little value, but quite the reverse is true. High-calcium limestone is the premium product of the limestone industry, and when properly used the term is helpful in presenting to a reading audience a very important industrial mineral. For thinking purposes, the term conveys the idea of a limestone with a lower limit or minimum standard of purity.

The volume of a raw or processed commodity produced is not directly comparable to its importance, but there is a definite relationship between the two. Only two groups of mineral raw materials exceed the volume of limestone produced—*coal* and *sand and gravel*. Tonnages of all limestone quarried or mined each year are remarkably large, and the postwar yearly average is about 200,000,000 short tons. What proportion of this total is high-calcium limestone is difficult to estimate, but probably it is 15–20 per cent of the total stone consumed. If high-calcium stone were available at comparable costs to all users, it would be demanded for about 50 per cent (by volume) of all limestone used. Unfortunately, high-calcium deposits are not common, and some are remote from industrialized areas.

Figure 1, although drastically simplified, illustrates the "initial flow" of limestone from the natural rock into use. Primary products of limestone as indicated are not weighted as to relative importance, and the following qualifications seem in order: The *natural stone* group is relatively unimportant, especially as a use of high-calcium limestone, because it includes such unspecialized uses as fill and breakwater construction. *Dimension stone* is important, but the high-calcium quality of much

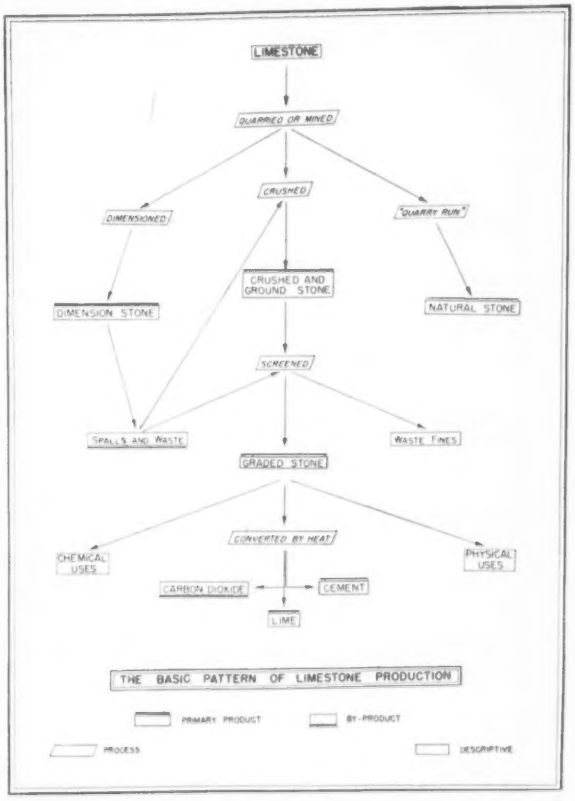


FIGURE 1.

building stone* probably is coincidental, since physical qualifications are most important to the building trade. The *crushed and ground stone* category includes most of the high-calcium limestone sold or used.

The uses of limestone are either primarily chemical or primarily physical, and the charts presented graphically illustrate each. The indicated uses do not exclusively demand high-calcium stone, but generally it is the premium raw material desired—with the notable exception of certain physical uses.

Primarily chemical uses of limestone are set forth in Figure 2. Most of the chemical uses of limestone actually depend upon the reactions of calcium oxide or lime; but if limestone rather than lime is directly added to the process, the material used is considered to be limestone. In some chemical uses, certain physical properties have an important effect, and stone is purchased only if it qualifies on both counts.

The physical uses of limestone shown in Figure 3 generally utilize a relatively impure limestone. Some of the deposits of impure limestone provide superior material when rated on the basis of severe physical tests. Many uses shown (Fig. 3) are chemical as well as physical and usually require a pure limestone. For example, Portland cement manufacturers can utilize limestones which have a wide range of purity, but they usually prefer a high-calcium stone so that their problems of chemical control are more simple.

* The excellent "Indiana, or Bedford, limestone" (Salem formation) is of high-calcium purity.

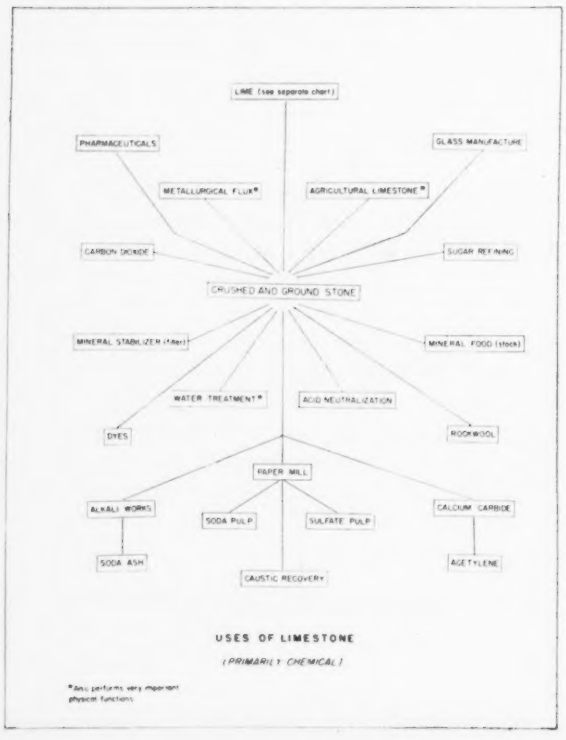


FIGURE 2.

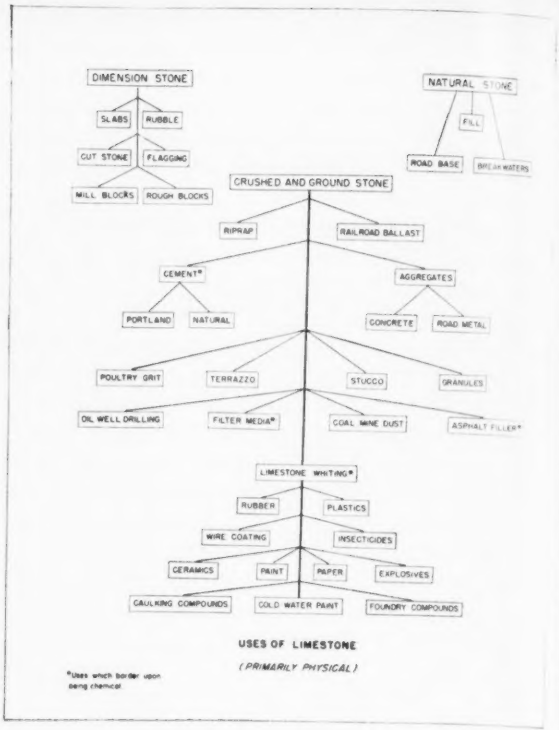


FIGURE 3.

An idea of the quantitative distribution of limestone, by uses, can be gained only by examining statistics. The United States Bureau of Mines is the chief source of nation-wide statistical information on production and consumption of limestone and its products. The Bureau's system of recording data necessarily "lumps" uses into the most representative classifications consistent with maintaining the value of the statistics.

Statistics cited in this report were selected from Bureau of Mines publications; and, since they do not classify the stone consumed as to purity or type, the figures should not be construed to represent only high-calcium uses. The conditions under which high-calcium stone is neither usable nor preferred (such as dolomite uses) have been eliminated (exceptions noted on charts). The Bureau of Mines compiles separate statistics for the major groupings of cement, lime, and stone, all of which use large amounts of high-calcium limestone. A breakdown of actual amounts of high-calcium limestone consumed in each group would be possible only if an exhaustive study were made. The 1947 production

statistics (latest complete reports available) represent a new high, to that date, rather than a typical year. Certain uses may be out of normal proportion, because some war-caused shortages still were creating especially large demands for stone.

Figure 4 is a graph showing consumption and cost of limestone for the nineteen largest volume uses in 1947, and Figure 5 is a similar graph for lime. Between the two graphs there are overlapping classifications, by name, but probably there are no repetitions of tonnages (except in the total lime column of the limestone-use graph).

Lime is properly calcium oxide, prepared by heating or burning limestone until carbon dioxide is driven off. Dolomite treated by heat sometimes is called lime, but in this discussion no high-magnesia content material is considered to be lime. The National Lime Association cooperated in preparing information on the uses of lime, and through the Lime Association records it was possible to modify the Bureau of Mines statistics by distributing captive or "miscellaneous" production to its proper classification. Figure 5 reflects these changes. The

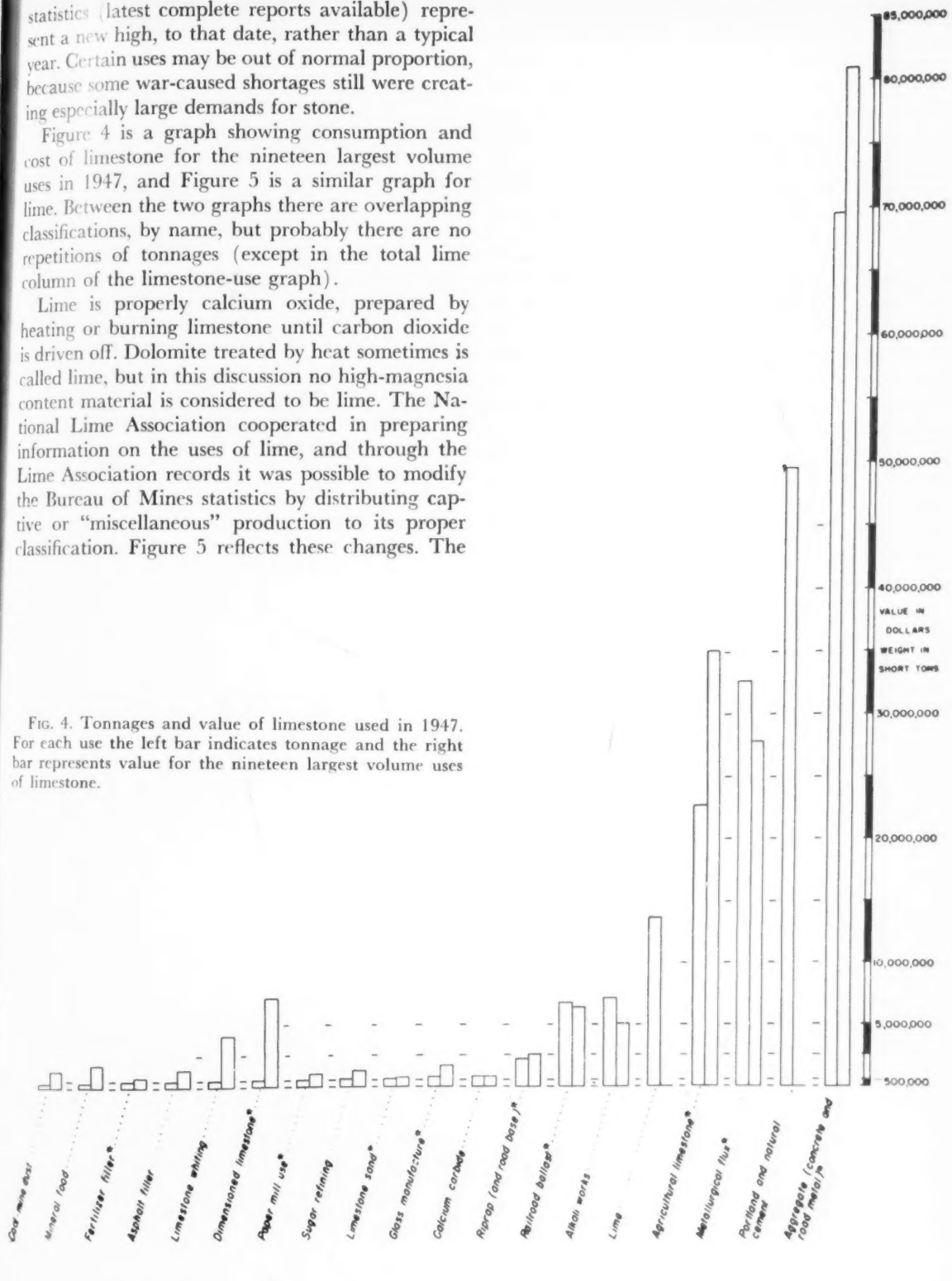


FIG. 4. Tonnages and value of limestone used in 1947. For each use the left bar indicates tonnage and the right bar represents value for the nineteen largest volume uses of limestone.

*These statistics include appreciable amounts of dolomite

Statistics are from UNITED STATES BUREAU OF MINES publications

major functions of lime in industry, as shown in Figure 6 for the various uses, are very much generalized, and when lime has more than one important function an attempt is made to select the more essential one.

As a product of limestone, lime has many of the same advantages, including a relatively low cost. Lime is produced primarily from high-calcium limestone, and is its most important single product.

Imminent depletion of certain of our mineral raw materials and increasing reliance on foreign sources have been forcefully brought to our attention in the postwar years. Perhaps the new realization that we are a "have-not" nation of many materials has led to recent suggestions that our reserves of high-calcium limestone also may be dangerously nearing depletion. Some of the reasons for apprehension concerning our high-calcium limestones are:

1. Many deposits of high-calcium limestone are known to be of limited size, even when first discovered, and there are relatively few formations of high-purity stone. Stated in another way, a pure limestone is a geological rarity, because very special

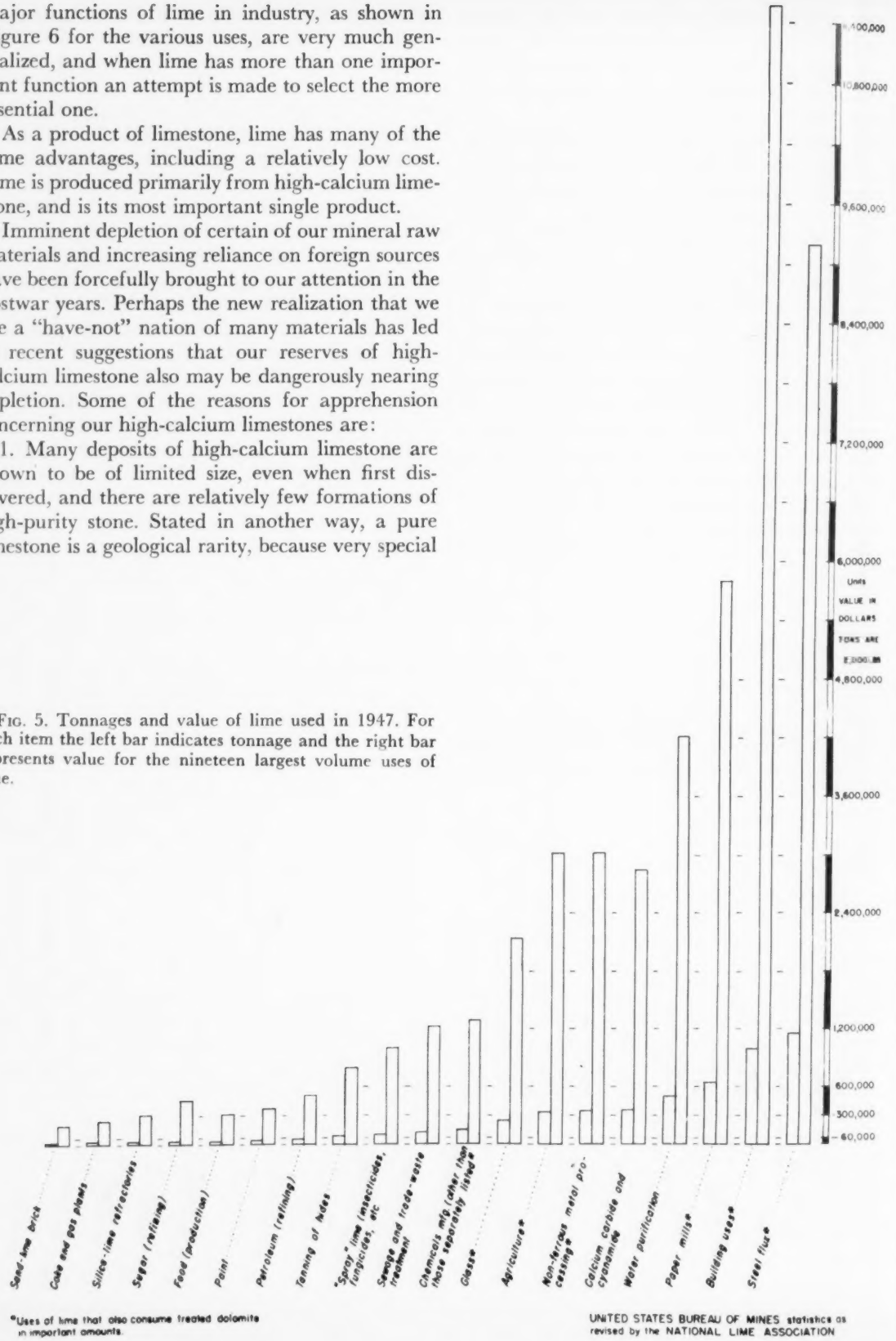
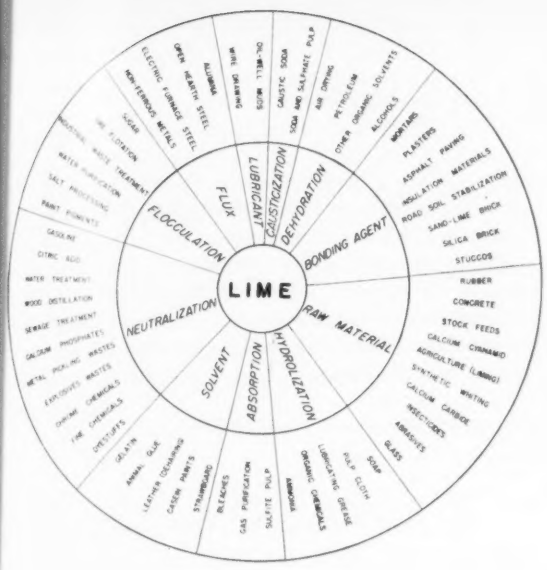


FIG. 5. Tonnages and value of lime used in 1947. For each item the left bar indicates tonnage and the right bar represents value for the nineteen largest volume uses of lime.

*Uses of lime that also consume treated dolomite in important amounts.

UNITED STATES BUREAU OF MINES statistics as revised by the NATIONAL LIME ASSOCIATION



FUNCTIONS OF LIME

IN IMPORTANT USES

FIGURE 6.

conditions were necessary for its original deposition.

2. Many deposits now being quarried or mined are scheduled for abandonment, either because of depletion, or because they are being worked to economic limits.

3. Companies can definitely regard as proved only relatively small reserves, because drilling and testing of stone usually proceed only a few years in advance of production.

4. The tonnages of high-calcium limestone production rapidly are increasing, and specifications constantly are becoming more demanding and rigid. In view of these facts a thorough study of high-calcium limestone reserves may be of value.

In spite of the apparent predicament, there is no danger of the United States running out of high-calcium limestone for centuries. Admittedly, there are not many rock formations which contain high-calcium limestone, yet the United States is fortunate in having a few extensive formations which consistently are of high-purity limestone, under many hundreds of square miles. Granted that there are problems of remote location and underground recovery, nevertheless the stone is available. Underground mining operations never can produce stone as cheaply as surface operations on shallow stone, and competition of the good surface deposits still exerts a tremendous influence on the industry. Many factors are involved, and in some areas underground costs now are more than compensated for by favorable considerations. Underground mining of limestone is far from new, and in recent years has grown to produce a large proportion of high-calcium limestone, yet the vast underground reserves scarcely have been scratched. As the ratio of need to cost increases, the source frontiers of this basic raw material inevitably will be extended, and the trend of this extension will be toward more intensive underground recovery of limestone.

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In September THE SCIENTIFIC MONTHLY (established in 1872 as *The Popular Science Monthly*) will celebrate the 102nd anniversary of the founding of the American Association for the Advancement of Science, and the 78th year of publication of this journal, by a special Historical Issue, which will be unique in concept, content, and scientific value. A Mid-Century Issue will be published in December.

Extra copies of both issues will be available, singly or in quantities.

BOOK REVIEWS

PROBLEMS OF CLIMATE

Physiology of Heat Regulation and the Science of Clothing. L. H. Newburgh, Ed. vii + 457 pp. Illus. $7.50. Saunders. Philadelphia and London. 1949.

IN World War II science added immensely to the arsenal of the fighting forces. Not only did new weapons and countermeasures come from the laboratories, but many contributions were made to maintain and intensify the efficiency of fighting men. No longer could armies retire to winter quarters when the weather got cold, no longer could campaigns await the end of rainy seasons. Troops had to be prepared to fight anywhere, at any time, regardless of environment. The unprotected human being is adapted to survive only within a relatively narrow range of atmospheric conditions. Adverse external stresses have to be compensated for by artificial means such as clothing.

The Division of Medical Sciences of the National Research Council set up a committee to find answers to the problems of climate and clothing. Review and interrelating of existing knowledge furnished some answers. For others new experiments and tests were required. The collective wealth of experience of that committee has now been issued in book form. This is a fairly complete summary of knowledge on human heat regulation and clothing.

The team approach was used and many different disciplines contributed. Anthropologist F. R. Wulsin introduces the theme interestingly in a discussion on how indigenous populations have adapted to climates. A major portion of the book deals with physiological reactions of the body to heat and cold, with chapters by H. C. Bazett on regulation of body temperatures; Sid Robinson on adjustments to heat; C. R. Spealman on adjustments to cold; Richard Day on the heat loss of various body areas; and L. P. Herrington on the range of physiological response. All these chapters have extensive bibliographies. On the physical side, basic information on heat transfer is summarized by J. D. Hardy, and C. P. Yaglou has contributed short chapters on thermometry and indices of comfort. One might have given here more emphasis and references to Buettner's book on physical bioclimatology and to work by other continental authors, e.g., Meissner, Dorno, Thilenius, Pfleiderer. The second portion of the book is devoted to clothing and clothing experiments. Physical properties of fabrics and new methods for testing them are described by Lyman Fourt and Milton Harris. Wartime laboratory and field studies on men are briefly reviewed by Forbes, Adolph, Robinson, Belding, Spealman, Van Dilla, Day, and Siple. A thought-provoking chapter by Siple on clothing and climate rounds out the book. This chapter does not attempt to summarize literature but is programmatic in character. It is a broad-brush treatment that much future research will have to elaborate in details.

The lessons learned for war purposes have many civilian applications. Whoever has had to bend to clothing conventions and traditions, often most unsuited to atmospheric conditions, will hope that science will make a dent here too.

H. E. LANDSBERG

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MAN AND HIS BELIEFS

Midwinter Rites of the Cayuga Long House. Frank G. Speck in collaboration with Alexander General. xiv + 192 pp. + 16 plates. $4.00. University of Pennsylvania Press. Philadelphia. 1949.

DR. FRANK G. SPECK began collecting material for this book in 1931 as comparative material for his studies on the Big House Ceremonies of the Delawares. And, although he continued his field trips to Six Nations Reserve in Ontario until as late as 1945, to attend the ceremonies and interview his informants, and the manuscript was completed shortly afterward, Dr. Speck never saw it in print. The author died a few weeks before this, his last book, came off the press.

This study is based on the author's field work with the group of Cayuga located at Sour Springs on Six Nations Reserve. The Cayuga constitute one of the extremely conservative Iroquois groups who cling tenaciously to the Long House religion as expounded by the prophet Handsome Lake. During the course of his investigations Dr. Speck attended nearly all this group's ceremonies and dances at least once, and some of them many times.

The book is divided into two parts. The first contains a short history and description of the Sour Springs Long House, a summary of the ceremonial-social organization, an account of the various spirit forces recognized by the Cayuga, a table of the annual ceremonial cycle, and a description of the officials taking part and the foods, instruments, and costumes used during the ceremonies. Part two contains detailed descriptions of the midwinter ceremony, the various medicine societies and their functions, the unrestricted curing societies and dances, sacred rites performed at the midwinter and other ceremonies, and social dances. The condolence rite for a bereaved family is described, and the book concludes with some philosophical remarks upon Iroquois religious belief.

Sixteen excellent plates and numerous text figures showing the Long House, Cayuga in costume, and ceremonial paraphernalia furnish the illustrations.

Hitherto the ceremonies of the Seneca of New York state were the only Iroquois religious beliefs of which detailed accounts have been published. This substantial contribution on the Cayuga by an experienced ethnologist brings out so many differences with the Seneca that one can only hope that similar studies will soon be made of other Long House groups at Six Nations and on other Iroquois reservations. The reviewer also hopes we can look forward to the publication of the songs collected for the Cayuga ceremonies now being studied by Dr. George Herzog. More texts for comparison with published Seneca material would have been desirable for the working ethnologist but perhaps would have made the book too weighty for popular consumption.

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Forgotten Religions. Vergilius Ferm, Ed. xv + 392 pp. $7.50. Philosophical Library. New York. 1950.

EDITOR Vergilius Ferm has performed a most valuable and laudable service to scholarship by bringing together this symposium of twenty-one truly forgotten religions, rarely described or studied. His introduction to the volume is a most lucid and penetrating analysis of the function and meaning of religion, which gives a purpose and unity to the collected essays.

Many of the ancient or forgotten religions here presented have been wholly reconstructed from a great diversity of residues. As such, they necessarily lack the vital pulse, the cultural function, and earthiness which working religions have as expressions of men's lives and values and fears and hopes. We know how devitalized, deformed, and devoid of their essence accounts of poetry or love or football or religion can be when we cannot see their function in man's scheme of things. Here, in the story of some religions the student has not been fortunate enough to be able to give even dry and lifeless accounts, for they are merely put together from shards and symbols. They do re-create a frame which, with our other knowledge, can somehow be filled in. In such a category belong the Sumerian, Assyro-Babylonian, Hittite, Canaanite, the religion of prehistoric Greece, and the mystery religions of Greece. More ample gleanings are available for other dead religions here described—such as those of Mithraism, Manichaeism, Mazdakism, and the Old Norse religions. In addition, the volume contains reports of still-living faiths whose followers are small in number and weak in influence within the maelstrom of contemporary religious or secular thought. These are the religions of Tibet, South America, and of the Australian natives, Eskimos, and the Navaho and Hopi tribes.

For the student of man's religious quest, which usually embraces sheer poetic symbolism, man's romantic or mystic representations of all human and social aspirations and institutions, and of natural forces and origins, neutral, benevolent or hostile, this book is an excellent investment. It contains novel material seldom encountered elsewhere. Many of the beliefs summarized have exerted a definite influence on our own culture; others merely aid us through their insight in understanding man in general, and the relevant specific cultures in particular.

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VALUABLE DATA

Selenium: Its Geological Occurrence and its Biological Effects in Relation to Botany, Chemistry, Agriculture, Nutrition and Medicine. Sam F. Trelease and Orville A. Beath. 292 pp. Illus. $4.50. Published by the authors. Columbia University, New York. 1949.

THIS small but useful volume is full of facts and information about selenium in nearly all of its aspects. It discusses and summarizes authoritatively the numerous publications on selenium since 1932, when it became known that grain from certain sections of the north central plains produced serious pathological effects in livestock by virtue of small amounts of selenium they may have absorbed from the soil.

The book consists of eight chapters arranged in an orderly and logical sequence. In the first the historical aspects of so-called alkali disease are discussed and integrated with selenium as the specific etiologic factor. In the second chapter the known selenium indicator plants—many species of *Astragalus,* Woody Aster, and others—are described and illustrated by appropriate photographs and diagrams. The third chapter is devoted to a discussion of the distribution of selenium in rocks and soils and the occurrence of seleniferous plants on outcrops belonging to the various geological systems, with data on geological formations bearing seleniferous vegetation in fifteen states where this subject has been studied intensively.

The fourth chapter deals with the mechanisms of accumulation of selenium in plants in relation to the selenium-supplying power of the soil and selenium-accumulating power of the plant. The reader will find here much valuable data on the selenium content of numerous samples of wheat and other grains in Colorado, Kansas, Montana, Nebraska, North and South Dakota, and Wyoming. A discussion of the chemical nature of the selenium in the plants, whether organic or inorganic, and of the effects of different types of selenium compounds on plant growth, is included.

The next three chapters, Selenium Poisoning in Animals, Selenium in Relation to Public Health, and the Prevention and Control of Selenium Poisoning, present a detailed analysis of the more important experimental and field studies on the pharmacology and toxicology of selenium carried out since 1932. The papers cited are well summarized, and the original data in the form of tables and charts freely reproduced, enabling the reader to get the essentials without the need of referring too much to the originals.

The last chapter, on the Chemistry of Selenium, gives much useful information on the technical aspects of the determination of selenium in soils and in biological

materials which should be of material aid to the chemist.

A bibliography of 287 contributions arranged in alphabetical order with reference to the first author in case of multiple authorship will be especially useful to students and research workers.

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UNDERSTANDING MODERN MAN

The Meaning of Anxiety. Rollo May. xv + 376 pp. $4.50. Ronald Press. New York. 1950.

WE HEAR it frequently said that this is the Atomic Age, the phrase designating new achievements in the realm of physical science. Related to these far-reaching changes in the physical world are personal, psychological reactions, many of which can best be described by the term anxiety. W. H. Auden, for instance, calls this "The Age of Anxiety"—a designation which Dr. May believes is well supported by evidence from many different areas of human activity. He says, for example, "If one penetrates below the surface of political, economic, business, professional, or domestic crises to discover their psychological causes, or if one seeks to understand modern art or poetry or philosophy or religion, one runs athwart the problem of anxiety at almost every turn."

The fears of man, especially the diffuse, free-floating anticipation of some catastrophe or personal threat, with the resultant feelings of uncertainty, dread, and the helplessness of psychic impotence, play a major role in the lives of many persons. The inability to cope with these undefined fears, these anticipatory reactions to symbols without referents, leads to affective disorganization and psychological unproductivity. This is manifested in the host of psychological defenses erected by the anxious person to control his undefined fears and in the wide discrepancy frequently found between an individual's level of ability and his level of achievement, or between his level of aspiration and his level of performance. It is of course the defenses against anxiety—the repressions, dissociations, phobias, compulsions, and so forth—which comprise the major symptom-picture of the neuroses.

Dr. May reviews theories of anxiety advanced by various persons—some philosophically, some biologically, and some psychologically orientated. Under the latter orientation he considers both the experimental work on fear and anxiety and the theories of such persons as Mowrer (anxiety and learning theory), Freud (theories of anxiety), Rank (anxiety and individuation), Adler (anxiety and inferiority feelings), Jung (anxiety and the threat of the irrational), Horney (anxiety and conflicting personality trends), and Sullivan (anxiety as apprehension of disapproval in interpersonal relations). This is followed by a consideration of anxiety culturally interpreted, summarizing mainly the views of Tawney, Fromm, and Kardiner. A summary and synthesis of theories of anxiety conclude the first half of the book. The second half is devoted to a clinical analysis of case studies demonstrating various manifestations of anxiety.

This book should be of value not only to psychologists and psychiatrists, but also to any person interested in a psychological understanding of modern problems—any person who, as Dr. May puts it, "feels on his own pulse the tensions and anxiety-creating conflicts of our day and who has asked himself what the meaning and causes of this anxiety may be and how the anxiety can be dealt with." Few of us, if any, can escape the need to face anxiety and to deal with it, either in ourselves or in others. This book may help us to deal with it more effectively.

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INTRODUCTION TO AFRICA

Problems of African Development. T. R. Batten. Part I, *Land and Labour.* viii + 178 pp. Part II, *Government and People.* viii + 180 pp. End-paper sketch maps. 7 *s.* Oxford University Press. London. 1947 and 1948.

IN THE overly modest words of the author these two small volumes are "intended for the general reader who has little time or opportunity to study larger and more authoritative works." For those who seek *multum in parvo,* these books have much to recommend them.

Their author is at Makerere College in Uganda and has had a long experience in both British East and British West Africa. He writes of African problems from a great breadth of knowledge and also with great sympathy. Throughout the entire work he has been able to maintain a remarkably unbiased viewpoint toward the native.

The discussion of the problems of African development has been oriented by those conditions which the author believes are necessary for true African independence: i.e., (1) sufficient economic development to finance the state, (2) a satisfactory scheme of education for the masses, (3) higher education for the leaders, and (4) the amalgamation of existing tribes into a native-recognized state. Volume I, after two chapters which cover general material, deals with economic problems. Inasmuch as the major resource of Africa is the land and the major occupation simple agriculture, a surprisingly wide range of topics is discussed. These include land tenure, subsistence versus cash cropping, animal husbandry, forests, water, soil, capital, labor, savings, the plantations, and export and internal trade. Volume II has an orientation similar to that of Volume I, but the main topics covered are even more diverse. It deals with the health, educational, tax, and other government policies which must be carried out before real native rule can be achieved.

This excellent book is not without its omissions and

errors. Perhaps the most serious is the general omission of comparisons between the indirect rule of the British and the more direct rule of other colonial powers in relation to native problems. As the book stands "Problems of Development in British Africa" would be a more apt title. In fairness to the author, however, it should be noted that, since he is a government servant, his work is subject to censorship.

Such errors as exist are minor ones. Although the author avoids the serious mistake of associating the removal of forest cover with a decrease in rainfall, on page 78 of Volume I he does include the dubious statement "that forests have the effect of causing rain to fall often and less heavily." Other errors occur on the four sketch maps printed on the end papers of Volume II. The inclusion of these maps is an excellent idea. It is unfortunate, however, that the railroad map shows a continuous rail line from Alexandria, Egypt, to Khartoum, Anglo-Egyptian Sudan, for actually there is a gap of nearly 200 miles between el Shellal, Egypt, and Wadi Halfa, Anglo-Egyptian Sudan. The same map fails to show the important rail link between Khartoum and Port Sudan. On the political map Italian Somaliland (Somalia) and Eritrea are omitted; Bechuanaland is shown as a part of the Union of South Africa; and the Sarra Triangle is included in the Anglo-Egyptian Sudan, contrary to the British-Italio-Egyptian agreement of 1934.

This is one of the best books that the reviewer has seen for the intelligent reader who wishes both an introduction to the African scene and an admirable summary of general developments in British Africa. For those who desire more detailed information, the "Short List of Useful Books" appended to each volume and arranged by subject matter subheadings will be useful.

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ACROSS THE FLORIDA STRAIT

Atlas de Cuba. Gerado Canet, in collaboration with Erwin Raisz. 63 pp. (Prepared in the Institute of Geographic Exploration at Harvard University.) Harvard University Press. Cambridge. 1949.

A BILINGUAL atlas of one of our closest Spanish American neighbors should be a welcome addition to inter-American, as well as to geographic, literature. For Cubans and the few North Americans who know Cuba intimately this graphic 63-page volume will serve to epitomize the geographic and social backgrounds of the republic, but for those whose knowledge of the country is sketchy it is a helpful, if idealized, compendium of information that will give the tourist, the businessman, and the average student an understanding of what goes on in the nation across the Florida Strait. Dr. Canet has brought a comprehensive knowledge of his country to a focus in this small volume, and Erwin Raisz has once again displayed his skill, experience, and imagination in translating dry facts and statistics into illuminating and colorful maps, diagrams, and pictographs.

The job is so well done that one hesitates to find any fault with it, but several shortcomings might be pointed out in the hope that this atlas will inspire many more for other countries. Some types of basic information are lacking or difficult to locate—for example, simple facts regarding areas of the country and of the several provinces and smaller political divisions. General and specific elevations are mentioned incidentally, if at all, and the hydrography of the island republic is neglected. Perhaps it was impossible for the authors to prepare a good reference book and, at the same time, to accomplish their aim of dramatizing the Cuban setting and showing "how [Cuban] life itself changes its own setting, creating new problems and new adjustments." Those who still like their facts and figures raw, rather than in figurines that must be counted, may be mildly irritated with some sections of the atlas, but no one can read through either the Spanish or the English text without acquiring a feeling of familiarity with Cuba, its people, and its economy. The authors have achieved their goal.

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BIOLOGY IN TEN EASY LESSONS

The Nature of Natural History. Marston Bates. 309 pp. $3.50. Scribners. New York. 1950.

TAKE a University of Florida graduate (class of 1927), a strong dose of insect taxonomy in Harvard's Museum of Comparative Zoology, a dozen years following mosquitoes as vectors of disease in the tropics, and a wealth of experience "in the field" under jungle conditions, and you have the basis for a thought-provoking book. This could have been a long one, or a tedious account. It is neither. Instead, Bates neatly outlines the problems arising from so many kinds of living things, then broadens his base to include ecological relationships.

Those of us who enjoyed "bull" sessions with Bates during his graduate school days may have regretted that he spent so long in Villavicencio, Colombia—even under the auspices of the Rockefeller Foundation. From a steam-heated laboratory in New England, tropical America may look like "the sticks"—and hardly the place to keep a good biologist. But it is those years in the tropics, plus others in equally warm countries, that provide the perspective which makes this book so different. It allows Bates to be far more objective in viewing such basic biological principles as migration. This phenomenon, for example, has been regarded as "perhaps the most distinctive phase of bird life." But the carefully plotted migration routes are quite misleading if migration as a whole is to be analyzed. Such north–south seasonal flights have been emphasized because "almost 100 per cent of the ornithologists have habitats that range but little south of Miami, Florida."

In contrast, "about 85 per cent of the different kinds of birds are purely tropical" and hence do not migrate in this sense. Migrations synchronized with breeding behavior do occur among the tropical 85 per cent, but the manner and complexities are too little known to form the basis for a general principle. And it is not correct to use the robin as a typical migrant, since it is not part of the majority. Like the ornithologists (but not most birds), it comes north of Florida. Biological principles need a broader background than happenings in Europe and North America.

The ecological concept of an animal-plant community that can be identified in terms of certain characteristic species which dominate the scene is another that does not stand up in the light of experience in warmer-than-temperate regions. "In the tropical forest," Bates says, "one looks in vain for any particular kind of organism that dominates in the sense that the pine or beech dominates its forest. . . . The idea works all right in the pine woods, but even in the temperate zone one must stretch the imagination to apply it to a lake or a stream or on the sea coast." Instead he views as "the essential element in the concept of the community . . . the interdependence of its various members to form a functioning unit. . . . The community, it seems to me, might be defined as the smallest group of such populations that can be studied and understood as a more or less self-sufficient unit."

Proponents of the doctrine of adaptations to the organic environment will find much support in Bates' experiences in the tropics. It is unfortunate that space and balance did not allow him to include more examples. Too often he stops with the generalization, as in stating that

> no naturalist who has worked in the tropics can doubt the reality of concealing coloration. It is common enough in the temperate zone for animals to blend so thoroughly with their environment that they are difficult to see, but temperate zone biologists, particularly if they spend most of their time in the laboratory, are able to shrug this off as an interesting but unimportant phenomenon, an accident of convergent evolution, a result of the operation of some irrelevant physiological process. . . . But such a biologist is badly shaken when one leaf on a branch he is holding starts to walk away; when the flying butterfly that he has been trying to catch simply disappears, though he could swear he saw the exact spot where it lit; when a patch of lichen on a tree gives him a severe burn and begins to crawl. . . . I cannot imagine anyone working in a tropical rain forest or on a coral reef and still doubting the purposive nature of the blending of organisms with their environment. . . . By "purposive" I mean directed toward a particular end, not random, incidental, or arrived at by chance.

The serious sides of natural history are enlivened at intervals by humorous comments. In a discussion of documentation of scientific statements—in this case on the point that cats eat mice—Bates manages a footnote reference to end all footnotes, or to make every reader seek them. Some of his analysis of the "natural history of naturalists" almost succeeds in having the book turn "into a missionary tract." This is not the central theme. His "errand is to arouse interest in an attitude, to explain a point of view, using facts only insofar as they may be necessary as illustrations." A large number of people can read the book with interest and profit. To many biologists it will draw attention to a wide neglect of tropic ecology and understanding.

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SCIENCE EDUCATION

Modern Science Teaching. (2nd ed.) Elwood D. Heiss, Ellsworth S. Obour, and Charles W. Hoffman, viii + 462 pp. Illus. $4.50. Macmillan. New York. 1950.

THE authors' preface announces this book's twofold purpose: "To serve as a textbook for courses in methods of science teaching" and as a "source book" for those "who wish to keep abreast of present trends in science teaching."

An over-all inventory reveals that the first edition of the book (1940), with 349 pages divided into twenty-seven chapters, is modified in the current edition to 462 pages, with nineteen chapters. Both editions have three major divisions. These divisions are addressed to about the same objectives: principles of teaching, science equipment, and visual and other sensory aids.

In keeping with their prestatement, more than passing emphasis is placed upon "trends." These trends are assessed, in the main, by reference to pronouncements of committees and editors of sections of yearbooks. This approach to a "science of education" has the limitations common to other types of authoritarian pronouncements in such fields as economics, sociology, and political science. The treatment of the objectives of science instruction, particularly, seems to be a mere cataloguing of various statements, without much indication of their relative merit or practicability. A reading of Stuart Chase's *The Proper Study of Mankind* would be in the nature of a corrective for the followers of "organization from above" (including the authors of the book under review).

The topics in the first section are: background (history); the learner, especially his psychology; selection and organization of content; interaction of content and learner, i.e., methods; "tricks of the trade" for both elementary and high-school levels; a full chapter on "evidence" as a unique contribution of science to the school curriculum; and a rather extensive survey of current efforts toward evaluating science as it functions in the public schools.

The 1950 edition corrects an omission in the earlier book by including two chapters on classroom, laboratory, and equipment needs for science teaching. It is noted that sources for most of what is offered are dated some fifteen or twenty years ago. This may be an indication that there is neglect by present-day students of science education of a restudy of the physical plant in relation to changed curriculum requirements.

Section three, constituting more than half the book, seems to overstress sensory aids for science teaching. The reviewers are fearful that such an extensive inventory of gadgetry may act as a deterrent for the novice in science teaching as he tries to assess the 179 pages of this part of the book.

In general, the authors have prepared a book of worth for the two purposes set forth in the preface. They have been handicapped by the constant limitations imposed when they had to make their treatment general, i.e., usable for all science teaching in the public schools. In their effort to attain that general approach they have, at times, made an undue use of phrases current among educators but not too attractive or meaningful to those trained principally in the academic program of science. They have exhibited a thorough familiarity with current research in science education, even though at times one has the impression that the "compendium of lists" is not too well integrated into a comprehensive overview. The position of the authors is not always evident.

One of the reviewers was a bit distressed to find that the authors had not found anything useful in the *Journal of Chemical Education* in all its years of publication. Is it possible, also, that they have never heard of *Chemistry* or the *Science News Letter* published by Science Service?

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BASIC RESEARCH AND CLINICAL APPLICATIONS

Research in Medical Science. David E. Green and W. Eugene Knox. viii + 492 pp. Illus. $6.50. Macmillan. New York. 1950.

THIS volume is a collection of articles by leading researchers in various fields of clinical medicine and the basic sciences. The editors have collected the articles to show the interrelationship and interdependence existing between basic research and clinical application of principles derived from such research. In addition, attention is directed to some of the problems encountered in basic research and to some of the advances that may reasonably be expected in the future.

No attempt has been made to include all the fields of medical endeavor. The material is not classified or grouped in any particular way except for four articles on pediatrics.

Articles appear in such general fields as anthropology, medical genetics, epidemiology, and problems in sanitary engineering. For the biochemist there are articles on immunochemistry, enzyme chemistry, and a history of the developments in chemotherapy. The field of bacteriology is covered by articles on bacteriophage, viruses, and Rickettsial disease. For the clinician the editors have included the four articles on pediatrics, work on rheumatic fever, hypertension, neurology, and psychiatry. Also included in this volume are articles on various specialized fields of physiology.

In no instance have the specialist authors restricted the work to the specialized field but rather have tried to place the information in relation to the other fields of medicine and biologic science and to indicate what may be expected in the future.

It is regrettable that some of the fields for which articles were originally contracted were not included because the desired authors did not submit manuscripts. Sex endocrinology and antibiotics are two fields in which much basic research has been accomplished in recent years, and articles on these subjects would be appropriate in this volume.

Generally, however, the book will be of interest to medical students, specialists in the basic sciences, and clinicians, for it affords an opportunity to study the fundamental relationship between basic research and clinical work in the fields covered by the authors. The book can be highly recommended to all who are interested in these problems. It will be of interest to laymen as well as to workers in the sciences because of its broad scope and concern with the problems of research.

The various authors have provided valuable bibliographies for the fields covered by the text.

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SERICULTURE

The Story of Silk. William F. Leggett. xiv + 361 pp. $5.00. Lifetime Editions. New York. 1949.

THE silk industry flourished in China for more than twenty centuries before the Christian era. About 120 B.C., Tsien T'sin, the silk city, began to trade with countries as far west as Persia; thereafter, the story of silk is the story of the rise and fall of the empires that successively strove to deprive China or its successors in sericulture of the silk monopoly.

The Romans obtained from the "Seric people" the silk fabrics that contributed to the luxury of the courts of the emperors, notably that of Heliogabalus, about A.D. 220. After the fall of the Roman Empire, civilization, as expressed by interest in silk, took refuge in Byzantium, where Emperor Justinian introduced the cultivation of the mulberry tree, then the raising of the silkworm and the processing of silk, by enforcing "planned economy" under state control.

A century later, "unification of the many Semitic nomad tribes of Asia Minor was accomplished by Mohammed . . . at that early date, texture art was not understood by the Arabs . . . but contact with silk weavers of Syria, Persia, Egypt and other conquered nations taught them the art of sericulture and silk weaving, but also stimulated their understanding of cultural values" as expressed in the ninth century by the events recorded in the *Arabian Nights*. The Mos-

lem influence spread westward to Spain and eastward to India, where the vogue of brocade under the last of the Great Moguls was recorded by seventeenth-century travelers, particularly by Fr. Bernier.

The Crusades had given the peoples of Western Europe a chance to become acquainted with sericulture, and to introduce that industry into Sicily or southern and central France: the first mulberry tree was brought from Syria to France in 1147, and silk began to be processed at Tours, then the residence of the kings, and at Lyons, early in the thirteenth century.

The peak of French and English costume luxury was reached in 1520 when Henry VIII of England met Francis I of France on the Field of the Cloth of Gold near Calais. Yet at that time the land which the Romans knew as the land of the Setes was still to Rabelais the "land of Satin," the *Mirabilia Mundi* that Marco Polo had described in 1275, the fabulous country which Columbus, and many after him, had failed to reach by sailing westward from Europe, but toward which Vasco da Gama had opened the maritime route along which the countries of Europe were soon to compete.

Early in the seventeenth century, King Henry IV of France, following the technical advice of Olivier de Serre, against the economic considerations advanced by his Secretary of State Sully, started the silk industry, which contributed to the splendor of Le Roi Soleil at Versailles and made Lyons the silk capital of the world. Meanwhile, England, climatically unsuited for sericulture, had obtained silk from India, through the agency of the East Indies companies, and had attempted to develop the West Indies into a substitute for the East Indies in the production of raw materials. These plans were frustrated by the American Revolution; eventually, as the Atlantic seaboard became connected with the Pacific, and silk from the Far East became accessible, New York developed into the largest silk market in the world.

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NATURAL RESOURCES

Grassland Historical Studies: Natural Resources Utilization in a Background of Science and Technology. Volume One, *Geology and Geography.* James C. Malin. xii + 377 pp. Illus. $2.50. The author. 1541 University Drive, Lawrence, Kansas. 1950.

Western Land and Water Use. Mont H. Saunderson. xi + 217 pp. Illus. $3.75. University of Oklahoma Press. Norman. 1950.

THESE two books are unlike except in their interest in the peculiarities of place. Malin is concerned primarily with the historical development of Kansas City to 1880, Saunderson with the United States west of the 100th meridian, its present land uses (excluding mining and urban land use). Both books would be more readable if maps had been used liberally.

Malin writes in his preface: "The grassland studies as they are being presented here, to be issued in three volumes, are frankly fragments put together with the minimum of organization, but with as much orderliness as seems either appropriate or necessary in any case." He uses about one sixth of the volume in the presentation of an excellent summary of the substantial work of the early geologists (1830–60) in the grasslands—principally their interpretations of stratigraphy in relation to the coal measures of this timber-poor region. Most of the remainder of the volume describes the development of Kansas City from its earliest days to about 1880. In this Malin relies almost solely on the editorial files of the city's newspapers. The story that unfolds is one of penetrating insight into the factors and processes of urban localization and growth as perceived by contemporaries.

Saunderson presents a massive array of pertinent facts and interpretations on Western resource use. He affirms his faith in the old-fashioned(?) idea that we should take care of the land. He closes with certain of the geologists who pontifically state that erosion and deposition have been going on at a high rate for a long time in the West—this truth by lame logic automatically justifying man's abuse of the land.

Insufficiency of water is among the greatest handicaps of the West. Most of the precipitation that falls is seasonal and is on only a small part of the whole region—sloping mountain land above six or seven thousand feet. If irrigators, power producers, and urban dwellers are to be able to use the water easily and efficiently it must flow from the mountains into the dry lowlands evenly throughout the year, without flooding or withering. This can best be assured by reducing immediate rapid surface runoff through maintenance of a good cover of soil and vegetation; this "blotter" effect, or "walking the water downhill," is further aided by check dams and reservoirs, and by good grass cover in the lower watershed areas that get occasional showers. Stability of billions of dollars of investments in the lowlands depends on the proper use of the very restricted, high, rough areas in the West on which the great majority of the precipitation falls.

The author's observations regarding the forest resource deserve summary. The "timber famine" will be upon us in the next twenty to forty years if current practices continue. Present prices, and perhaps those that will hold for some years to come, are only high enough, generally speaking, to cover "cost of cutting," inadequate for "cost of cutting plus cost of production." Most of the good commercial timberland is private property (much of the publicly owned land in the West is either without trees or has poor, inaccessible stands or is of more value for watershed protection); therefore, any ameliorative program must work to encourage and to make profitable a system of sustained yield for the private timber owner. This involves education, low-cost seedlings, fire protection, tax policies designed for forests (only a few states tax forest lands differently

than their farm "yearly return" lands), and shoring up of the credit value of forests for lien purposes.

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BRIEFLY REVIEWED

External Morphology of the Primate Brain. Cornelius J. Connolly. xii + 378 pp. Illus. $10.00. Charles C Thomas. Springfield, Ill. 1950.

THESE important studies were made largely on the skull collection of the U. S. National Museum Divisions of Physical Anthropology, the so-called Hrdlicka Collection. The number of infrahuman brains (from the lemur to the gorilla) was 330; the human brains (white, Negro, and Malay) numbered 120 adult and 25 fetal (white and Negro) at different fetal stages of development; the total number of brains studied was 538. There are chapters on the brain during fetal growth; on the brain of the newborn and of children; on brain and race; on anthropoid and human brains; and on the brains of prehistoric or fossil man and of man today.

In both the anthropoids and man today the number of brains studied appears sufficient to eliminate or evaluate the significance of individual variations. These studies reveal no consistent differences (superiority or inferiority) in cerebral geography or cerebral mass in the white, the Negro, and the Mongolian people. The title of the book might suggest a superficial treatment of human evolution and human anatomy, but this is far from the truth. Functionally, the cerebrum is the most specific or characteristic item in man's internal anatomy, in comparison to other mammalian species. To be sure, the author describes the superficial anatomy of the dead brain. But all the profound problems related thereto are presented according to the method of science and discussed in the true spirit of science. This book is a valuable contribution to the understanding of man.

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Introducing the Insect. F. A. Urquhart. x + 287 pp. Illus. $5.00. Holt. New York. 1950.

THIS is the latest of the several textbooks now available for the beginning student of entomology. It is somewhat different from the others of its class in that it is more truly elementary; that is, except for some of the butterflies, no particular attention is given to individual species, but instead groups of species having in general the same life histories are treated as units. The opening chapters are devoted to discussions of the why, how, and where of collecting insects, and to general remarks on the structure of the insect body and the classification of insects. The author's method of introducing the reader to the subject of dichotomous keys is a happy one; first, a key is written to cover four common and familiar objects—a nail, a wood screw, a bolt, and a carpet tack. This is followed by a key to four common and quite dissimilar insects. After studying these, no one should have trouble in using any properly constructed key.

The greater part of the book deals in generalities concerning the major orders of insects—their life histories and economic importance. In the case of the butterflies and large moths, more attention to individual species is given, probably on the assumption that the reader already recognizes different species at sight. The work is well illustrated with line drawings and four colored plates. Each couplet in the key is accompanied by a marginal sketch, and larger, more elaborate shaded drawings are scattered through the text. The colored plates are all devoted to butterflies and moths, and are well executed (except for the Luna moth, which is much too blue). A good book for its purpose.

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New Ways to Better Sight. Harris Gruman. 205 pp. Illus. $3.50. Telegraph Press. Harrisburg, Pa. 1950.

THIS book was published by the author himself. In a generally pleasing style he writes about Nearsightedness, Contact Lenses, Your Eyes and Your Nerves, and other everyday topics which concern most of us. In order to explain a particular subject he frequently relates case histories and refers to Wilma or John or George or any of numerous names. This method is apt to be less factual and less taxing than the regular textbook approach. He has drawn on illustrations supplied by the Bausch and Lomb and American Optical companies, which are not sufficiently descriptive. The author has aimed to befriend his reader by mentioning eye disorders without getting himself involved. For that reason an index was not found necessary. He has lent color by relating historical facts in interesting language.

In reviewing a book of this type intended for the lay reader, it is important to detach oneself from one's technical background. It is the opinion of this reviewer that the author has selected a good title and followed it up with a readable book written in a matter-of-fact fashion.

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The Principles of Scientific Research. Paul Freedman. x + 222 pp. Illus. $3.05. Macdonald. New York. 1949.

THIS book will be of interest to young scientists, and still more to those who wish to become scientists. The glamor, pitfalls, difficulties, and excitement of their future life are simply told, and fatherly advice is given. But an experienced scientist will find the book slightly

flat and commonplace. What is true will be well known to him, what is fresh and new will be debatable. An example of the commonplace is: "Those who have had the benefit of a first-class university education in science will have an advantage over those who have had to rely to a considerable extent on self-education." An example of the debatable is: "In the absence of adequate knowledge, imagination may cause harm, while caution cannot do so." I don't agree. Too much caution may kill courage, and to trust one's imagination requires courage.

To summarize briefly, the book is pleasant but not exciting. It reminds one of books on "How To Become a Writer" or "How To Become a Painter." The trouble with such books is that the really good writer or painter neither needs nor ever reads them. The same is true of scientists. The remaining question is whether the book can make a mediocre scientist a little better. It might.

The part devoted to the historical development of research is very impressive, and it shows the author's great erudition. I was most impressed by the information about subjects that I know least. Information about the one I did know seemed to have been gained secondhand.

LEOPOLD INFELD

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Documentation. S. C. Bradford. 156 pp. $3.00. Public Affairs Press. Washington, D. C. 1949.

THE nature, purpose, and technique of documentation. Composed in the main of papers previously published in the *Proceedings* of the British Society for International Bibliography and of excerpts from a contribution to the *Communicationes* of the International Federation for Documentation. Of interest to librarians, bibliographers, and research workers.

Color Psychology and Color Therapy. Faber Birren. ix + 284 pp. Illus. $4.50. McGraw-Hill. New York. 1950.

AN interesting collection of color information. Coming from several fields, it constitutes something of a synthesis, but it will be of relatively little use to any kind of specialist.

Cross-Country, Geography for Children. Paul R. Hanna and Clyde F. Kohn. 160 pp. Illus. $2.20. Scott, Foresman. Chicago. 1950.

A FOURTH-GRADE geography in story form, with 28 maps and 142 other illustrations, many of them in full color. Detailed lesson plans are provided in a Teacher's Edition at the same price as the pupils' text.

The Centennial of the Sheffield Scientific School. George A. Baitsell, Ed. xiv + 206 pp. Illus. $3.00. Yale University Press. New Haven. 1950.

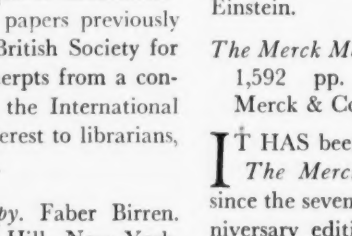
IN addition to the Silliman Lectures (1947) by Ernest O. Lawrence ("High Energy Physics"); Linus Pauling ("Chemical Achievement and Hope for the Future"); W. M. Stanley ("Virus Research"); and G. W. Beadle ("Genes and Biological Enigmas"), this volume contains other material relating to the "Sheff" Centennial.

Albert Einstein. His Work and Its Influence on Our World. Leopold Infeld. vi + 132 pp. Illus. $2.00. Scribners. New York. 1950.

A DISCUSSION of Einstein's contributions to our world—special and general relativity, his role in quantum theory, and modern theories of the structure of the universe—by the distinguished theoretical physicist who has done much work in collaboration with Einstein.

The Merck Manual of Diagnosis and Therapy. (8th ed.) 1,592 pp. $4.50; thumb-index edition, $5.00. Merck & Co. Rahway, N. J. 1950.

IT HAS been half a century since the first edition of *The Merck Manual* was published, and ten years since the seventh edition. Preparation of the Golden Anniversary edition was begun in 1946. More than one hundred clinicians throughout the United States served as authors or consultants under the direction of the Merck Medical Division. Up-to-date discussions of antibiotic therapy, crystalline vitamin B_{12}, cortisone, ACTH, and medical experience gained in World War II are included.



CORRESPONDENCE

THE RED PROCRUSTEANS

THE article on planning of Soviet science in your June issue [pp. 390–94] was most interesting.

During the past five years the writer has attempted to keep track of the strange gyrations in planning and execution that have afflicted genetic research and application in the Soviet Union. This record makes it clear that the Soviet scientist who must keep step with the shifting concepts of science promulgated by political decree is beset with many perplexities. What has happened in genetics, as it can be reconstructed from official Communist documents, leads to the suspicion that Dr. Brožek gives a rather idyllic picture of the nature of planning for research in the Soviet Union, and perhaps an illusionary estimate of its fruitfulness.

Ashby, for instance, was able to observe no evidence that the agricultural conquest of the Arctic and Subarctic was anything more than rather pathetic wishful thinking. We should remember that Sergei Vavilov is writing about the future, which seems always to be rosy in the Soviet Union. The case of his brother Nikolai, and the story of scores of other geneticists, record the *performance* of Soviet science by fiat: not of the ardent hopes of its proponents. There the picture has a more somber hue.

That geneticists are not the only scientists whose path is strewn with conceptual booby traps is strongly suggested by the hectic career of Academician Eugene S. Varga. This strange story was presented with full documentation in the *American Economic Review* for March 1949. An abstract appears in the *Johns Hopkins Magazine* for May 1950. All American scientists would do well to read and ponder this record alongside Dr. Brožek's article.

Varga, warned repeatedly that his studies must fit the official mould, was stubborn. He was not sure he could see "the cracks which have formed in the economic foundations of capitalism" that Marxist doctrine insisted were there. When he could not see them, *and when capitalism refused to follow the schedule of postwar collapse the Marxist line demanded,* Varga was purged and ultimately he recanted—in the face of the facts—just as the geneticists had been forced to do.

The carefully documented record of Varga's troubles confirms what the story of Michurinist genetics tells, that the master minds of Soviet science have gone Procrustes one better. In genetics and economics the Procrusteans of the Kremlin have made their conceptual bed of conformity to "dialectical materialism" shrink and stretch unpredictably at the whim of the Politburo. The plight of a toiler in the vineyard of Soviet science who has to try to guess how tomorrow's concepts will square with yesterday's version is, one gathers, hardly a happy one. Let every scientist ponder these two pronouncements. Said *Pravda* on August 27, 1948:

> The Presidium of the Academy of Sciences and the Bureau of the Biological Department *forgot the most important principle in any science—the party principle. They pegged themselves to a position of political indifference and "objectivity."* The U.S.S.R. Academy of Sciences forgot the instructions given by V. I. Lenin that "partisanship" is inherent to materialism, and that materialism, whatever phenomena are being considered, must stand openly and directly on the viewpoint of a definite public group.

Said V. I. Lenin some years earlier: "The scientific concept of Dictatorship means neither more nor less than unrestricted power, absolutely unimpeded by laws or regulations and resting directly on force."

That is what Soviet science actually rests on. *Pravda* speaks as the official voice of the Party. *Any science* is answerable to Party discipline: not only genetics or economics. It is not the data one has to keep one's eye on in the Soviet Union. It is the gyrations of a panel of madmen in the Kremlin.

Viewed in the light of such considerations, the imposing orderliness of Academician's Vavilov's pronouncement regarding scientific planning has a bizarre and sinister flavor. Let it be remembered that planning with regard to research in Western science still has to base ultimately on the nature of the data. "Planning" in genetics and economics in the Soviet Union has nothing to do with the data. The data are something that one manipulates to fit the current dialectical concepts of that "great coryphee of science," as Marshal Stalin was recently described by Academician Lysenko. Stalin's whims rather than the state of scientific knowledge determine what goes into next year's "Science Plan."

Not all areas of scientific endeavor seem to be blessed by the intense scrutiny that genetics and economics enjoy at the present time. But that does not alter the fact that "the most important position in *any science* [is] the party principle." That is a basic doctrine which makes every Soviet scientist a candidate for the Procrustean bed of conformity to political whim. Scientists of the Western world should not let themselves be misled as to this fundamental issue.

For seven long centuries the people of the Western world have struggled to free their minds from the ancient and still-powerful dogmatism of arbitrary authority. We know how difficult it is to free our thoughts and interpretations from the social context in which we learn to think and feel and believe. But the ideal of Western science is to try to apprehend reality within limitations that cannot be denied. In its essence, Marxist science is a flight into the past. It is ancient word-magic at a very primitive level. It should be recognized as such.

ROBERT C. COOK
American Genetic Association

MORALITY OF THE MACHINE*

REGARDING Professor Elgin Williams' contribution, "The Morality of the Machine," in the February issue, I would point out that his basic assumption of *extreme inequity* in income distribution, as instanced by his statement that the wealthiest 10 per cent receive as much income as two thirds of all the rest combined, is grossly inaccurate.

Back in 1918, it is true, the 10 per cent at the top did get 34 per cent of the entire income. This is not two thirds of all the rest, though within shouting distance. However, since then a radical change has occurred in the distribution of income. There has been a steady shift, as illustrated by the percentage of total income received by those having $25,000.00 or *more* left after paying income tax. Thus, in

1918	they totaled	6.4	of the	entire	income;	and	in
1932	"	"	3.4	"	"	"	"
1938	"	"	2.5	"	"	"	"
1944	"	"	1.3	"	"	"	"

In twenty-six years their take dropped to one fifth what it was in 1918.

In the same way, considering all those who received $5,000.00 or *less*, their total take increased from 81.2 per cent in 1918 to 89.6 per cent of all wage and salary payments in 1944. They also received 83.1 per cent of all rents in 1944 and 69.4 per cent of all interest and dividend payments.†

As of today, the eminent statistician and economist, Dr. W. I. King, has estimated that the income of all who retain $10,000.00 or more after income taxes, when put together, would not exceed ten billion dollars, or about 6 per cent of the total income.

Is it not clear that Professor Williams' basic assumption is wide of the mark? And does not his remarkable edifice, built on so insecure a foundation, fall to the ground?

ALVAN L. DAVIS

Waterbury, Connecticut

* Correspondence on this subject closed.

† Weighted average of all three sources of income equivalent to approximately 87.5 per cent total U. S. income; thus an increase from 81.2 per cent to 87.5 per cent.

DR. GILBERT AND HIS PREDECESSORS

MR. ESPENSCHIED in his comment on my article about William Gilbert may not have noticed that on page 260 I gave credit to Peregrinus for anticipating Gilbert in the use of the *terrella*. It might be added that to give him this credit is perhaps to overrate his importance, as his *terrella* would better be called a *cielito*. He thought of the spherical lodestone as a tiny celestial rather than terrestrial globe, with the poles corresponding to the poles of the heavens.

A careful reading of Peregrinus' *Epistle*, moreover, will show that this remarkable thirteenth-century empiricist believed the magnet to draw its virtue from the celestial poles. This point he labored in opposition to those who imagined that this virtue came from the Pole Star, which he knew was not exactly at the celestial north pole. A reader may be misled by Peregrinus' occasional reference to the "poles of the world." "World" is used in its older sense of "universe." Gilbert, as I mentioned on page 260, undervalued Peregrinus, who was indeed the best of his forerunners. Still the good doctor's criticism that his predecessor was off on the wrong track when he attributed the directive force of the compass needle to the poles of the heavens was sound. Peregrinus was wrong in his theory of what caused the needle to point approximately north, and his *cielito* did not play the methodological role of Gilbert's *terrella*.

Mr. Espenschied also mentions Mercator as having anticipated Gilbert in understanding the cause of the verticity of the compass needle. Mercator, who was a cartographer, was interested in determining the latitude and longitude of the north magnetic pole on the earth's surface. By prolonging the axes of declination needles at two points he fixed the north magnetic pole at the intersection of the prolongations, somewhere northwest of Bering Strait. As inaccurate as his result was, his feat was indeed astounding. It is a far cry, however, from this achievement to the full realization and proof that the earth is a magnet.

Gilbert's greatness lies not so much in the fact that his *De Magnete* was "a compendium of the magnetic knowledge of the time" (to use Mr. Espenschied's words) as in the fact that he was the first to demonstrate various properties of the magnet and of the earth by the methodical experimental-inductive technique of modern science. If we include proof, or even the deliberate, planned project to try to find rigorous proof, as an essential part of discovery, then it is no inaccuracy to call Gilbert the originator of the sciences of magnetism and terrestrial magnetism.

RUFUS SUTER

Army Map Service
Washington, D. C.

ANOPHELES REPLIES

(*See page 346, May 1950*)

We skeeters *like* to fluoresce—
It adds aplomb to our egress
And éclat at the entré joints
By lighting up our better points
Without the usual bitter quills,
As "Look! He's lit up to the gills!"
We're set apart (by sprays like these)
From common grades of Anopheles.
We're registered, typed; our plasmodium
Is tested on a drop-slide podium.
The PHS's monthly mention
Makes us Insects of Distinction.

AMOS KETO

Philadelphia T. R. MCCREA